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TROUT FISHERIES

IN

NEW ZEALAND

Their Development and Management

by

DERISLEY F. HOBBS

Senior Fishery Officer [fresh-water] Marine Department

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PART I

Historical

INTRODUCTION

THIS BOOK is a review of the practices adopted for the maintenance of stocks of trout in New Zealand in the light of results of recent research work both here and abroad. Its aim is to assemble, primarily for the layman, such factual matter as may aid in an appraisal of past operations and, equally, to assemble, in convenient form, such data as should be in the possession of organizations responsible for the formulation of future policies. It was apparent in the search for data, as will be evident to the reader of much which follows, that information which might have settled many controversial points is wanting. Thus the book may serve a useful secondary purpose if, in addition to showing what is known, it emphasizes gaps in our knowledge and, more especially, gaps of a kind which might be bridged through the co-operation of local administrative bodies.

To enable the reader to study more critically, as he reads it, the evidence presented here, major conclusions have been brought forward, instead of being listed at the end, as is more usual. The conclusions drawn from available evidence are:—

(1) Although many environments have changed, sometimes for better, possibly more often for worse, there is no evidence which suggests that throughout the country generally in the last sixty years there has been a progressive deterioration in the capacity of most waters to produce trout.

(2) In the case of only a limited number of waters has sufficient evidence (usually from anglers' diaries) been found to warrant comparison of angling conditions in recent times with conditions shortly after trout were established. The general tenor of the evidence is against the view that any serious general deterioration of stocks has occurred in the last fifty years. There is evidence of well-maintained average size of brown trout from earliest times to the present in some waters, but more commonly of a very early drop in average size, which continued in some waters until about 1900, and less commonly later than that. There is evidence of a tremendous increase in the total angling effort since before 1900. There is little doubt that in many waters in recent times there has been a sustained higher yield than in earlier times, although some degree of sharing of this yield has often caused a drop in the catch of the individual angler.

(3) The demand for angling, as evidenced by licence sales, has for a long period tended to increase more than proportionally to the increase of population.

(4) The geographic distribution of angling does not accord with the spread of the human population, but is greatly conditioned by the quality of angling offered in different parts. Apart from the Rotorua and Taupo

areas, much fished by visitors, the highest proportion of local resident anglers is in the south and south-eastern parts of the South Island.

(5) In most districts the greater part of revenue has been invested in hatchery work.

(6) In the initial acclimatization phase of fisheries work, hatcheries served a useful purpose in permitting the proper reception of eggs from abroad and the assembly of stocks for distribution.

(7) From very small seedings, made in most cases very long ago, stocks have developed well or poorly, according largely as the environments have been suitable or otherwise for the natural propagation, survival, and growth of trout. To-day distribution and density of stocks reflect in most cases the suitability of waters for natural propagation rather than the extent of releases of artificially propagated fish.

(8) Artificial propagation, as practised for the maintenance of stocks in New Zealand, does not add significantly, if at all, to the total quantity of trout, and is not usually an appreciably more efficient process than natural propagation.

(9) Eggs have been collected from wild stocks where they have been most easily obtainable, rather than from otherwise unexploited stocks or from stocks in waters where it was known that eggs had a particularly poor expectation of survival.

(10) The exploitation of different stocks for their eggs includes cases where not only the fish stripped, but many more, were denied access by these operations to good spawning grounds; but it includes one case where most eggs removed have been in excess of what could have been accommodated by available spawning ground.

(11) Artificial propagation, even when it absorbs most of the revenue for maintenance of fisheries, cannot be applied to more than a very small fraction of the total eggs produced. Therefore, even if it could be applied to eggs taken solely from waters where there was an abnormally high expectation of loss, it could not effect a significant increase to total stocks.

(12) Quantities of eggs handled in hatcheries have comprised small fractions of those available in a very few waters, and their transfer has not effected more than a nominal reduction of stocks in districts where collected or more than nominal additions to stocks in districts where resulting young fish have been released.

(13) In particular waters—namely, certain lakes where conditions have favoured survival exceptionally—small but useful fisheries have been maintained by transfers of fish, some of which have been drawn from hatcheries.

(14) Preoccupation with the artificial propagation of the fragmentary part of the total eggs handled in the hatcheries has led to the neglect of the reasonable protection of natural spawners and of their progeny and the neglect of other possibilities of fisheries management, certainly not more, and possibly less, speculative than artificial propagation.

(15) Hitherto, restrictions on angling, such as bag limits and size limits, have been considered important for the conservation of stocks. However, bag limits have had no significant general effect, and size limits have had a possibly significant effect only in certain waters.

ADMINISTRATIVE AUTHORITIES

The early development of trout fisheries in New Zealand took place between 1865 and 1875, partly as a result of efforts of individuals, but mainly through the activities of acclimatization societies formed by groups of settlers. At first some such organizations received recognition and sometimes financial assistance from Provincial Governments. Later, under a central Government, formed in 1876, societies received statutory recognition as local wild life administrative bodies. By regulations made under the Fisheries Act, 1908, rights are granted of collecting fishing licence fees and of expending such funds for specified purposes. The right to make regulations for the protection of stocks is reserved to the Crown.

Membership of acclimatization societies is open to all holders of fishing or shooting licences who elect councils to direct activities. Effective control is strictly retained by such councils; the delegation of wide authority to employees is not usual. Since 1900 the number of societies has varied, usually between 25 and 35, as sub-division and amalgamation of territories has taken place. The title of these organizations is to-day and for long has been an anachronism, because since before 1900 their activities have very largely been limited to the management both of introduced species long domiciled in New Zealand and of native species.

The only areas not controlled by councils of licence holders are the Rotorua and Taupo Districts of the North Island and, since 1945, the Southern Lakes District in the South Island in which the Department of Internal Affairs exercises the powers of an acclimatization society. In the South Island the Marine Department operated salmon hatcheries at a few points in the territories of acclimatization societies, but controlled no territory.

In addition to sales of trout ova made between societies, sales of ova of brown trout were for a period made by the Marine Department. More recently the Internal Affairs Department has been the chief source of supply of eggs of rainbow trout.

No privately-owned hatcheries are operated in New Zealand. The recognized local fisheries authorities assume full responsibility for the maintenance of stocks in all waters in their respective districts. However, for a short time following the introduction of trout a few small private hatcheries operated, and sales of young fish were made by societies to individuals for stocking public and private waters. In recent years there has been no private stocking of waters. Access to waters is rarely denied to anglers. Rivers and lakes, equally on private and public property, receive the attention of acclimatization societies.

HISTORICAL SKETCH

Although in Europe it was known possibly as early as 1758 (*vide* Armistead—1898) that salmonid ova could be taken from fish, fertilized and incubated, the regular operation of hatcheries there did not begin until nearly a hundred years later. Although eggs had been hatched earlier in England, Armistead (1898)

speaks of his Troutdale hatchery erected in 1868 as "the first real hatchery ever erected in this country (England) on commercial principles." Calderwood (1924) corrects a State of Washington claim that its hatchery, opened in 1866, was the first in the world. It was, however, one of the first in the Americas.

As in certain districts of New Zealand hatcheries have been in regular use since as early as 1868, it is clear that in this country their development was to a considerable extent parallel to their development abroad. It is important to note that **New Zealand did not accept a practice which longer experience elsewhere had shown to be economically sound and necessary.**

Armistead (1898) in the appreciation of trout culture in his opening chapter instances especially the establishment of trout in New Zealand as evidence of its "grand success." Later writers, led by Calderwood (1924), have been careful to distinguish between what might be termed the "acclimatization" and the "maintenance" functions of hatcheries. The maintenance function of hatcheries will be considered at some length later on. As regards the acclimatization work, it is necessary to realize that **hatcheries were started in New Zealand, not because of any advantages they were thought to afford over natural processes, but because it was essential to have proper facilities for the reception of trout at the only stage at which they could then be safely carried—namely as eyed-ova.**

A somewhat hardier fish, the perch *(Perca fluviatilis)* was introduced as a grown fish—(*vide* Arthur, 1881)—and as such was distributed without artificial hatching. The whitefish *(Coregonus albus)*, despite successful hatching of many imported eggs, proved a total failure. Early and fairly widespread releases of both Atlantic *(Salmo salar)* and quinnat *(Oncorhynchus tschawytscha)* salmon failed in all waters. Eventually each was established in one river system, and the quinnat (Hefford, 1929) spread by natural dispersal to other systems. Attempts to extend the range of each by artificial propagation failed almost entirely. Despite extensive artificial propagation, the American brook char *(Salvelinus fontinalis)* was to prove a failure in nearly all waters. Rainbow trout *(S. irideus)* were successfully introduced from hatcheries into many rivers, but failed in many others.

Total or partial failure in the case of these several species or the success with grown perch are no more evidence against the value of hatcheries for acclimatization purposes than the success with brown trout is evidence for it. Probably the same results would have obtained had it then proved practicable to import and distribute small or even well-grown trout.

As regards extended distribution in New Zealand, artificial propagation enabled supplies to be made available at a cost. However convenient hatcheries may have been for such a purpose, it has been shown that they were not essential by the fact that, in addition to "green" eggs from wild fish and sometimes eyed-ova from natural spawning redds being collected, fry, fingerlings and even adult fish have from time to time been captured in streams for transfer to others. Available evidence simply shows that when—and largely because—transport facilities were inferior by to-day's standards, it usually proved most practicable to transport and hatch ova. Fish culture, in its broadest sense, was a partial success. As eggs were hatched under artificial conditions in New Zealand before there were stocks here to reproduce naturally, the use of the earliest hatcheries was simply incidental to

the transference of fish and had to be undertaken irrespective of beliefs as to the relative merits of artificial and natural reproduction. Calderwood (1924) distinguished between the acclimatization and maintenance functions of fish culture, and with Hutton (1929) and others he accepted the results of early New Zealand work as evidence of the value of hatchery operations for acclimatization purposes. It is therefore emphasized that the conditions which earlier may have necessitated the use of hatcheries in acclimatization of fish are no longer operative to a like degree.

It is not possible to fix a precise time at which New Zealand hatcheries changed over to maintenance work. The gradual transition took place earlier in the South Island than in the North. Further, long after brown trout had been widely distributed and maintenance releases were being made, rainbow trout were being released in many of the same waters in the hope of establishing this second species. Even to-day, to a limited extent, rainbow are being released into waters at present containing none. It is clear, however, that the principal function of hatcheries became one of maintenance after a very short period of acclimatization endeavour in the South Island and after a longer period in the North. That is to say, after such periods fish were propagated mainly in the hope of helping wild stocks to withstand man's depredations.

To-day most of the angling in the South Island and the southern portions of the North Island is provided by brown trout; still further north the rainbow is the dominant species. It is to the propagation of these two species that most of the hatchery work is directed. With a very few interesting, but unimportant exceptions, the rainbow in the South Island is restricted to inland lakes and streams entering or leaving them. In the North Island, although the rainbow is the dominant species in the centre portion, which includes the well-known Taupo and Rotorua fisheries, the brown trout is found in relatively important numbers at least as far north as Kaihu, about 100 miles beyond Auckland City.

Until recently the propagation of salmon was carried out chiefly in the hope of establishing the Atlantic or quinnat species in further rivers. This work was almost wholly abortive. The Atlantic salmon is still confined to the system in which it was originally established. The quinnat salmon has dispersed naturally to most major rivers on the east coast of the South Island from the stream of original establishment, and has shown a pronounced disinclination to provide a return commensurate with the effort in most waters to which man has transferred it.

Perch, which are locally numerous, more especially in coastal lakes, are not propagated. Tench (*Tinca vulgaris*) and catfish (*Pimelodus cattus*), neither of which has been propagated, occur so uncommonly as to be unknown to most anglers. Only a few isolated colonies occur of the one time extensively propagated American brook char.

It is not proposed to consider in detail the history of all attempts to establish different species of fish in New Zealand. Such ground has been covered fairly adequately by Thomson (1922). Henceforth consideration will be limited to species which provide the mainstay of angling and of them especially to brown and rainbow trout. The term "brown trout" is here used as synonymous with *S. trutta* Linn. and as inclusive of such possibly varietally different forms as sea trout,

Loch Leven and Scotch Burn trout. Similarly "rainbow trout" may be regarded for present purposes as synonymous with *S. irideus* Gibbons.*

The early history of the introduction of brown trout and their distribution is given by Nicols (1882), by Arthur (1878, 1881, and 1883) and by the annual reports of various acclimatization societies. Later observations on the status of stocks in different parts of the country were given by Sherrin (1886), Spackman (1892), and Hamilton (1904). Thomson (1922), in his more general work, drew largely on these sources of information and summarized as well activities in regard to the introduction of rainbow trout, quinnat, and Atlantic salmon. Lack of complete records of activities of acclimatization societies and Government Departments makes the compilation of a comprehensive history impossible at this date. However, such practical ends as this paper may serve call mainly for a brief general account of past work and a more critical study of activities in certain typical districts. Considered in chronological sequence the history of New Zealand trout fisheries has been somewhat as follows:—

1867–70—Following on the recent successful establishment of brown trout in Tasmania, small consignments of ova, collected in at least one case from natural spawning redds in that country, were imported to Canterbury and Otago. Some resultant fry were released in these two provinces and in Southland. Others were retained to provide breeding stock.

1871–75—Further importations were made from Tasmania, this time for the Auckland Province. The progeny of earlier Canterbury and Otago importations were distributed widely in these provinces and supplied also to Southland and Wellington. Certain Canterbury and Otago rivers were opened for angling in 1873.

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*Snyder (1940) and others are followed in their preference for this specific name to *S. gairdnerii* (on the grounds that the original description of the latter fish was so vague that no particular trout could be recognized with certainty from it) and as inclusive of such possibly varietally or specifically different forms as steelhead, *S. gairdnerii, S. clarkii,* or *S. henshawii.* Although Thomson (1922) records the introduction of the last two, it would appear that, even if the fish were then correctly designated, they are not known to have thrived and no progeny have since been recognized.

Records of the Auckland Acclimatization Society show that the first successful importation of rainbow trout eggs was in April, 1883. Other early importations of rainbow eggs died in transit. Some fry were released that year in waters where stocks later developed. Others were retained for stock fish. Subsequently eggs were collected from the stock fish and later from their progeny at Lake Takapuna and still later, at the Waimakariri. It would appear that it was from this one importation in 1883 that stocks developed and were distributed to and became abundant in most, if not all, waters in which rainbow are at present found. Any small importations of rainbow ova of different origin, made long after, do not appear to have been released except where fish of the original stock had already become very abundant.

Records of the Marine Department show that a former officer of the Department met at San Francisco, a Mr. La Motte, who stated that he, personally, had collected the ova sent in 1883 from steelheads at the Russian River and that then only steelheads were handled at the hatchery which he managed for the Great Western Railway Company.

This is a probable rather than a certain history of the origin and development of the present stocks of so-called "rainbow" trout in New Zealand. The uncertainties arise because complete records of all Acclimatization Societies and of a private importer in Canterbury are not available and because there was early confusion of the names of brook trout and rainbow trout in the Auckland records. It seems also that ova of trout of the cut-throat group may have been imported still earlier by the Auckland Society but, if so, their progeny were released in waters where stocks failed to develop. While it seems improbable that any cut-throats were retained and mixed with the rainbow breeding stock, such a possibility cannot be wholly excluded.

Specimen rainbow from Hawke's Bay and Otago were submitted to the late Professor J. O. Snyder of California. Snyder's report is quoted by Hefford (1926). Tables which accompany the report sent to the Marine Department show a scale count on the lateral line of from 128 to 139 for four Hawke's bay fish and from 124 to 140 for three Otago fish.

1876–80—Releases of brown trout were extended to the provinces of Westland, Nelson, Marlborough, Taranaki, and Hawke's Bay, and further waters were opened for angling. Otago was outstandingly the major source of supply of ova and continued so for a further 40 years. The Otago eggs were at first obtained partly by raiding natural spawning redds, partly by stripping fish captured on redds and also from pond stock. In most districts with hatcheries, breeding stock was kept in ponds, especially in Canterbury and Wellington, which were rapidly to become important sources of supply. Large-scale trapping of wild stocks came later.

It seems clear that the dominant and probably the exclusive purpose for which hatcheries were operated up to this time was to distribute still more widely the brown trout already established in many waters. Arthur (1881) reports that by the end of this period 150,000 young trout had been put into 150 streams and lakes in Otago alone, and that in ten named waters they had increased enormously in numbers and that in many other waters they had increased and established themselves, though to a lesser extent. The Lee and Deep Creek, from single releases of 98 and 100 young trout respectively in 1869, were stated by Arthur to have become "full of trout." From Arthur's three papers (1878, 1881, and 1883) one gathers that the initial Otago releases were of fish of two or three inches, and that thereafter most commonly fish of one to one and a half inches were put out. In Southland and elsewhere, apart from Otago and Canterbury, the establishment of brown trout was as yet in doubt.

Early reports and Arthur's papers show that up to the end of 1880 the principal societies had released about 350,000 brown trout, 450,000 quinnat salmon, 29,000 American whitefish, 4,500 Atlantic salmon, 1,700 perch, 1,200 American char, 100 Tahoe trout, and a few tench, golden carp, and European char. The brown trout were very largely the progeny of a few small initial importations. Most of the other fishes were imported as ova and hatched for early release. On the credit side of hatchery operations at this time there was the successful establishment of brown trout in a number of waters. On the other hand, no stocks are known to have developed from the hatching of ova of either species of salmon or from ova of whitefish, char, or Tahoe trout. Perch, tench, carp, and catfish, introduced as grown fish, "took" in different waters. Of these, perch and carp were later to become fairly widely distributed, but only perch were to achieve even local importance as an angling attraction.

1881–85—This period saw in the South Island probably the first conscious change from hatching trout eggs to provide young for wider distribution to hatching for the maintenance of established fisheries. By this time most of the eastern and southern river systems, which to-day are well-known angling waters, had been stocked with brown trout. Arthur (1881) says, in reference to hatchery work: "As it is believed that the stock in any river will decrease (when fishing occurs) from year to year if left to itself, the Otago Society is very properly spending a large portion of its funds in these operations." Again, the report of a South Island conference of acclimatization societies held in 1883 is cited by Sherrin (1886): "Our experience is that in many streams the stock of trout has not succeeded well of late years. We find that where they were numerous a few years ago they have diminished in numbers to an abnormal extent, even when

supplemented in their natural spawning by thousands of fry artificially reared. . . . It would be presumptuous in the present state of our experience to pretend to say that trout are established so firmly that they will not suffer if left to themselves." Hardly had trout become established before fears were voiced that the Golden Age of angling had passed. Even at so early a date, the conference report mentions "over-fishing," and expressed grave doubts as to the ability of societies to maintain stocks if the licence fee were so low that everybody could fish.

In the North Island, where, as in the South, activity had been divided between quinnat salmon and brown trout, the salmon work proved abortive and, generally, the establishment of brown trout lagged behind that of the South. From the many small early North Island societies, two were to emerge to a pre-eminence still maintained. These were the Wellington Society in the southern half of the island and the Auckland Society in the north.

In Wellington, activity was ill-organized before 1884–85. However, in 1885 it was reported that in the Wainui-o-mata (stocked by private effort with 100 small brown trout in 1876) fish had "thriven to an almost unprecedented extent," and that they continued to increase despite "excessive fishing, poaching," and the removal of "large numbers" to stock other waters. Trout were first caught in the Hutt River in 1885. Reports were coming in of trout being seen in other waters.

In Auckland, although acclimatization endeavour was properly organized as early as 1867, no satisfactory results had come from releases of brown trout by the end of this period, probably because these fish were released mainly in small streams, adjacent to Auckland city, which were never to become worth-while angling waters.

This period is of special importance in that it saw the importation by the Auckland Society in 1883 of consignments of rainbow trout eggs, from one of which 5,000 young were hatched. It was from the resultant stock that eggs were obtained for distribution elsewhere in New Zealand, and this early importation provided the basis of most of our present-day rainbow stocks. Some of the 1883 fish were released in that year; the next releases were of their first progeny.*

Thomson (1922) states that rainbow eggs were forwarded to the Canterbury Society in 1885, but I am unable to find records of any having reached the South Island prior to 1888, when a private breeder obtained some (*vide* Auckland Report, 1934), or of having been handled by the Canterbury Society until about 1895 (*vide* North Canterbury Reports).

1886–90—Eggs of brown trout were sent by the Auckland Society to Lake Taupo in 1886, and young fish of this species were sent to Lake Rotorua from Tauranga in 1889. The Wellington Society was rapidly developing into the major distributing agency in the North Island, and was, by the end of this period, releasing fish not only in the outlying portions of its own territory but considerably farther north. In the North Island, stocks were sufficiently established to offer some fishing in streams of the Wairarapa and in those nearer to Wellington city, but the bulk of the waters to the north had yet to prove themselves, and the establishment of the rainbow was yet to come.

1891–95—Spackman (1892) states of brown trout: "In the North Island they

*Contemporaneous reports speak of these fish as "brook trout"—an error corrected in later reports.

have been successfully introduced into most of the rivers as far north as Taranaki on the West Coast and the inland portions of Hawke's Bay on the eastern side. . . . With the exception, however, of the Wellington province, no part of the North Island affords as yet the sport which can be obtained in the South." He states that they were taken for the first time in Hawke's Bay in the season 1891–92, by which time brown trout were also well established and offering fair sport in Taranaki. In a few portions of the Auckland district, trout were showing up, and rainbow were being taken in the Patetere area. It is clear that through much of the North Island the purpose of liberations of trout was still essentially an acclimatization one.

1896–1900—In this period the results of past stocking with brown trout became apparent in the lower portion of the Manawatu system, where Fergusson (1888) reported total failure after 15 years of liberations. This appears to have been the last of the present recognized Wellington brown-trout waters to have achieved success. Rainbow trout, which now interested the Auckland Society to the exclusion of all other species, were also being handled in increasing quantities by the Wellington Society, which was able to claim success in one stream, the Makuri, and this species was commanding some notice in the South Island. In the Auckland District, worth-while angling could be obtained in only a few small waters. The major lakes of the central portion of the North Island, Taupo, the Rotorua series, and Waikare-moana, which were quickly to become the most famous of New Zealand angling waters, now received serious attention for the first time. By arrangement with the New Zealand Government, the Wellington Society dispatched quantities of ova to the western coast of the South Island, and in the North Island it released quantities of fry in the Taupo and Waikare-moana areas.

In 1895 and 1896 brown-trout fry went to Taupo. In 1896 and 1897 brown-trout fry, together with upward of 6,000 rainbow fry, went to Waikare-moana. In 1897 the Wellington organization made what was probably the first release of rainbow in or above Lake Taupo—namely, of a consignment of 5,000 fry "to the headwaters of the Waikato River before it runs into Lake Taupo." In 1897 and 1898 the Auckland Society made the first official releases of rainbow in the Rotorua area, and in 1898 and 1899 it released rainbow in the Waikato and tributaries shortly below Lake Taupo.

The 1901–10 period, more especially the early portion of it, saw the development of abundant stocks in the North Island lakes. Most of the waters of the Auckland District which to-day offer fishing came into bearing as the stocking of the upper Wanganui system was completed. Thus the acclimatization phase of activity largely ended in the North Island, where societies at long last followed the South Island ones in concentrating on maintenance work. In small measure in the South there was a reversion to acclimatization work as societies there strove to establish rainbow in many of the waters which had long supported stocks of brown trout. Here and there, but on a decreasing scale, such attempts are still made.

General.—In the foregoing, reference has been made almost entirely to the activities of a few major societies. This is because in most cases adequate reports of the early work of many smaller organizations are not available, and, in any case, the activities of the few major ones, from which the others drew most of their fish, dwarfed those of the more numerous smaller bodies. The Otago and Canter-

bury (later, North Canterbury) Societies were initially the principal sources of supply of brown-trout eggs for the whole country. Later this work was shared with them by the Wellington Society from 1889 to 1914 and by the Marine Department from 1907 to 1928 and by the Southland Society from 1924 to 1935. The Auckland organization supplied rainbow-trout eggs to various parts of the country, principally from 1897 to 1912. Later, supplies for sale were drawn largely by the Tourist and Internal Affairs Departments from the Rotorua area from 1907 to 1927 and, more recently, mainly from the Taupo area.

Shortly after 1900, quinnat salmon became established in the Waitaki River system and, in the following 20 years, this fish spread by natural dispersal to most of the major river systems on the east coast of the South Island.

It is more difficult to learn when the Atlantic salmon became established in the Waiau River system, because little angling took place before 1920 in the Te Anau portion of this system, where it appears first to have become abundant. The species is still restricted to this one river system. Stock (undated) records releases of these fish in the following portions of the Waiau system: Orawia in 1893 and 1897, Mararoa in 1898, and Laka Manapouri in 1900. In 1901 a fish that was probably a salmon was taken near the mouth of the Waiau. Larger releases were concentrated in a Lake Te Anau tributary, the Upukeroro, between 1908 and 1911. In 1916 an undoubted salmon was taken at the mouth of the Waiau River. In 1922 three more were caught there. In 1923 salmon were first taken inland in the Te Anau area.

The stocking of the Waitaki with quinnat and of the Upukeroro with Atlantic salmon were carried out by the Marine Department. Its subsequent transfer of ova from these waters to stock the Hokitika River in Westland with quinnat and the Wanganui River in the North Island with the latter species failed to yield results.

FEATURES OF THE DEVELOPMENT OF FISHERIES

I. Environmental Change

Before evidence both as to past and present size and abundance of trout and as to the increase of exploitation is reviewed, it is intended to discuss various happenings which have influenced, for better or for worse, the actual environments in which stocks of trout are produced. It will become evident from what follows that, even without man's direct or indirect intervention, environments are subject to frequent change, that natural change may have been greatly stimulated by man long before trout were introduced, and that, while much of the change since that time may have been harmful, much may have been beneficial.

Miller (1925) estimated that the primitive forest and shrub covering of New Zealand had been reduced through the agency of fire by as much as one-third between the advent of the first human inhabitants (probably 1,000 years earlier) and the beginning of settlement by Europeans in 1840.

Since 1840 there has been a tremendous increase in numbers and extension of range of imported grazing and browsing animals, much indigenous forest has been milled and much has been burnt to make way for pasture and tillage. Coal and gold-mining industries have been developed, and have employed water for

power, and have discharged waste products into natural waterways. A multiplicity of secondary industries has arisen, some of which have found rivers useful, ready-made drains for their wastes. Sewage and farm animal manure enter streams in quantities previously unknown. Increasingly, water has been impounded by dams and diverted for town supplies, for watering livestock, for the irrigation of farm lands and the production of electrical power. Here and there natural channels of rivers have been altered, swamps have been drained, and, commonly, low-lands have been cut by networks of drains to give improved run-off. In places imported willows and watercress have so infested streams as to impede flow.

All such changes, whether made to the streams themselves or to their catchment areas, have had effects which may have influenced, more or less directly and to different degrees, the suitability of environments for trout and for the forms of life which feed them and which otherwise condition their abundance. Some such changes began long before trout were established; most have increased and extended since that time. The difficulties of assessing accurately at this late date the effect of such changes are insuperable. At the most, it is possible to distinguish between natural erosive processes and the acceleration of such processes by man's activities, to indicate where and when changes in the vegetative covering may have led to accelerated erosion, and to discuss possible effects of certain other types of changes by reference to known effects in a few cases.

EROSION

The sharply etched mountain tops above the original bush-line, the extensive flood plains of Canterbury and Southland, ancient landslips, and the loose shingle beds and flood-beds of Westland rivers, in parts where no forest has been cut, are all evidence of long-continued natural erosive processes and of the naturalness of change in rivers.

Man's interference with the primitive vegetative covering of catchment areas has generally led to the reduction of the vegetative coverage or its replacement by other vegetation, often less suited to the control of run-off. The report of the Committee of Inquiry (1939) on the maintenance of the vegetative covering gives particulars of the extent and nature of the replacements of the primitive covering and the location of the areas chiefly affected. Principal changes given for a total area of 66,000,000 acres, from primitive to present times are:—

Reduction of the area in forest and shrubs from 41,000,000 to 23,000,000 acres;
Reduction of the tussock grassland from 17,000,000 to 14,000,000 acres;
Deterioration of much of the remaining 14,000,000 acres, and replacement of the covering of the 21,000,000 acres of forest, scrub, and tussock by 18,000,000 acres of grass, 1,500,000 acres of cultivated land, 800,000 acres of exotic forests, and 850,000 acres now required for boroughs, roads, and railways.

EROSION IN NORTH ISLAND

In the North Island the general areas within which accelerated erosion is said to be most apparent include the following: Coromandel Peninsula and the eastern aspects of ranges extending south from it as far as Tauranga; the drainage areas of rivers entering the Pacific from Opotiki, east to East Cape, and south as far as southern Hawke's Bay; country along the line of the Tararua and Rimutaka

ranges, inland in the Wellington Province, but taking in hills extending to the south-western coast west from Lake Wairarapa; the whole of Taranaki exclusive of country in the Egmont drainage area and exclusive of a narrow coastal belt extending south-east to the Wellington Province.

It is emphasized that these are areas in which accelerated erosion is most general and severe, but it is neither strictly limited to these areas nor does it occur in all parts of them.

These areas include many waters in which trout have never been established and others in which trout at all times appear to have failed to attain a satisfactory abundance. Such waters include most on the Coromandel Peninsula, most entering the coast between Opotiki and Gisborne, and almost all waters of Taranaki between the Mokau River and the Wanganui, except those rising on Mount Egmont. Thus, the recognized trout streams which may have been affected are principally those in the vicinity of, and south from, Gisborne, throughout Hawke's Bay, those comprising the Wanganui River system, the Rangitikei River, the Manawatu and its tributaries above the gorge, the Ruamahunga and its east-draining tributaries, and streams entering the southern portions of the coast between Foxton and Lake Wairarapa.

The main rainbow trout fisheries of the country, in the Taupo and Rotorua areas, are outside those places substantially affected by accelerated erosion.

No accurate information is available to make possible a comparison of past and present angling in the Gisborne area or in the northern and central portions of Hawke's Bay. The main portion of the Wanganui River system, below the vicinity of Taumarunui, appears never to have been very productive of trout, and waters above this point lie outside the area where effects of erosion are most noticeable.

The Mangawhero sub-system of the Wangaehu lies within the affected area; yet the Waimarino Acclimatization Society in recent years invited neighbouring societies to remove trout from these waters because of their great abundance. The upper eastern drainage area of the Rangitikei River and the principal catchment area of the Manawatu River above its gorge are in eroded areas. In the Rangitikei trout are still reasonably abundant, but data on past abundance are not available for comparison. In the case of the Manawatu River system, however, it will be shown in a subseqent section that there has been no significant deterioration of stocks since shortly after trout became established.

The principal streams in areas of accelerated erosion south from the Manawatu include the Ruamahunga and its western tributaries and the Otaki, Waikanae, Hutt, and Wainui-o-mata Rivers. Some evidence of past and present states of stocks in the last two rivers is given in a subsequent section. There is little to suggest that the Otaki and Waikanae Rivers at any time in their history offered substantially better fishing than in recent years, or that the activities of man have affected the forest in the areas of heavy precipitation in their catchment areas as greatly as did an exceptional wind-storm in 1937. The Ruamahunga and the east-draining tributaries of it and of Lake Wairarapa seem most likely to have been adversely affected, for along some tributaries land was opened up for settlement right back to the head-waters, and extensive burning of beech forest occurred.

Reference to forest fires causing heavy loss of trout in waters of the Ruamahunga system is made in the Wellington Acclimatization Society's report of 1897. Losses from this cause were widespread in 1896, and there are reports of extensive clearing and burning operations in 1891 in the Eketahuna area. It would appear that much of the destruction of forest in the Wellington district took place before, during, and very soon after the establishment of trout.

Phillips (1931) attributed differences in the abundance of invertebrate fauna in certain of the more rapid streams of the Wellington Province to differences in the extent of interference with the primitive covering along their banks. The differences in the abundance of invertebrates are such as might be expected between relatively stable streams unaffected by deforestation and those affected by accelerated erosion. However, the evidence offered is only as to the absence or presence to-day of indigenous trees on banks immediately adjacent to a very few sampling areas and not as to differences in the major and higher portions of catchment areas where precipitation is greatest.

It is very doubtful if the head-waters of the group of streams with poorer faunas—namely, the Otaki, Hutt, Ruamahunga, and Waiohine, have been subjected by man to more change than those of the other group—namely, the Waikanae, Kaiwarra, Belmont, Whakatikei, and Waipoua. Great differences in the stability of river-beds and in the nature and quality of immediate riparian covering are apparent in some parts of Westland, where catchment areas are still relatively unmodified by man. There is no reason to believe that similar variations did not exist in the Wellington Province before trout were introduced, although it is possible that in the district generally differences have since sometimes become more extreme as a result of man's actions.

EROSION IN THE SOUTH ISLAND

In the South Island, according to the report of the Committee of Inquiry, accelerated erosion has become most apparent where the tussock covering has deteriorated and some beech forest has been destroyed, on the eastern highlands stretching from Marlborough through to Southland. Streams entering the west and north coasts and streams rising on the eastern and southern plains and coastal hills are not affected, although major rivers traversing the eastern and southern lowlands from the main dividing ranges may be. Three of these major rivers—the Clutha, Waitaki, and Hurunui—have in their courses extensive lake systems, which permit the precipitation of solids and which tend to control run-off. Others include the Rakaia, Rangitata, Ashburton, Waimakariri, and the Waiau-uha, Clarence, and Awatere. The last three flow almost wholly through deteriorated lands, but do not appear ever to have supported trout fisheries of any significance.

The catchment areas of the other four lie back behind the Canterbury Plains. All four have offered sometimes good, but somewhat variable, fishing for sea-run trout near their mouths, and have higher up usually carried fairly sparse stocks. Except very near the coast, the gradient of these rivers commonly exceeds 15–17 ft. per mile, which appears in New Zealand to be the usual maximum for

reasonably productive trout water, where streams have gravel beds and flow through readily erodible plains.*

Some details of the early and more recent trout-fishing history of the Rangitata and Ashburton Rivers are given in a later section. The establishment of salmon in these waters long after trout became established makes it unsafe to ascribe changes in the abundance of trout to physical change, such as increased frequency and severity of flooding, rather than to biological change arising from the establishment of salmon.

Smaller South Island rivers with portions of their catchment areas in affected country include the Aparima, Oreti, Mataura, Opihi, Orari, and Ashley. Of these, extensive reaches of the first three and a shorter length of the Opihi have gradients of less than 16 ft. per mile and are still extremely productive of trout. Production is aided in the Oreti, Mataura, and Opihi by extensive tributary systems in lowland areas. The past angling history of the Oreti is fairly well known, and is discussed in a later section, where reference is also made to records of past and recent angling conditions in the Aparima and in portions of the Mataura and Opihi systems. The Orari and Ashley may from time to time have held more trout than in recent years, but, except very near to the coast, their gradients exceed 16 ft. per mile, and it seems unlikely that these two were ever streams of high quality for a long period.

In general, the position in the South Island rivers is of accelerated erosion tending to be restricted to the catchment areas of rivers draining to the east and south coasts, and probably affecting most severely major rivers which have never been first-class angling waters. The impression from general observations is that, given an abnormal absence of flooding for a few years, stocks of trout tend to build up, even in loose-bedded shingle streams. It is possible that rivers, in which formerly stocks varied from fair to poor, now vary between poor and very poor, because of greater frequency and severity of flooding. There is no evidence, however, that, because of accelerated erosion, important rivers which formerly offered very good angling now offer very poor angling.

It is possible that deterioration of trout stocks as a consequence of the deterioration of the covering of catchment areas of streams would have been greater in degree and easier to trace had not much of the burning of tussock land and beech forest taken place before and during the period of the establishment of trout. Arthur (1883), referring particularly to Otago, says that grass fires were just as common before as after angling began. Burnett (1927), discussing the Mackenzie Country in South Canterbury, says that the burning of the mountain valleys began as early as 1859, and was almost complete by 1875.

VEGETATION ON RIVER BANKS AND IN FLOOD CHANNELS

Impressions arising from an examination of many streams in different parts of the country are that, except in the spawning season, trout avoid heavily

*This observation on the significance of gradient is strictly limited in its application to streams of the character mentioned. There are many rivers elsewhere in New Zealand, especially on the slopes of Mount Egmont, where brown trout are plentiful in waters where the over-all gradient exceeds 20 ft. per mile. Such rivers, however, have beds of rock or of large stable boulders, and exhibit much greater differences of gradient within a mile of water than is usual on erodible flood plains.

shadowed water, and that the penetration of some direct sunlight is required by trout. If this is so, then the removal of forest covering from the margins of narrow streams where formerly trees met overhead may not have been without advantages. Phillips (1929) gave an opinion that deforestation might cause (a) the loss of cover for flying stages of aquatic insects and their consequent destruction by birds and other predators and (b) loss of food and cover for river-bank insects, which, he says, in well-bushed areas form a considerable item of trout food.

The native fantail (*Rhipidura flabellifera*) and to a much less extent the tomtit (*Petroica toitoi*) take mayflies in the air and off the water surface. Both birds were formerly greatly more abundant than now. They are not found along streams lacking marginal shrub or tree cover. No efficient introduced mid-air or water-surface feeding species has replaced them on streams where heavy marginal cover is no longer found—except the chaffinch (*Fringilla coelebs*), a not very numerous species, but one which may be observed taking mayflies much more commonly along bush streams than in open country. The very large colonies of native black-fronted tern (*Sterna albistriata*), which frequent the open shingle river-beds, especially of Southland, appear to feed in spring and early summer almost exclusively on mayflies taken off the water surface. There is no evidence that this habit has been recently acquired, or that it has been intensified following the removal of marginal cover.

Three terrestrial forms of trout food to which Phillips directs most attention are all beetles: one is found in marginal boulders; another, the manuka beetle, is, as its name implies, most abundant in manuka and other shrub growth; and the third is a grassland beetle. As grass, shrubs, or shingle have replaced former forest cover on many stream-banks, and elsewhere willows and other exotics flourish, it is not clear that deforestation has reduced food supplies of terrestrial origin.

DEVELOPMENT OF EXOTIC TREES AND SHRUBS

In the North Island there has been a partial replacement of indigenous forest by indigenous and introduced shrubs along the banks of rapid streams and often by extensive development of willows on the banks of less rapid streams. In parts of the South Island where the primitive covering, especially of tussock grass at higher altitudes, has been greatly reduced, replacement by shrubs, indigenous or otherwise, has been slight. However, especially in the South Island, there has been a very extensive development of willows, gorse, broom, and tree lupins along the banks and in the flood-beds of rivers in lowlands areas nearer the east and south coasts.

At the present time, when much publicity is being given to the possible consequences of unrestricted deforestation in the upper portions of catchment areas, the possible consequences of wide establishment of certain exotic trees and shrubs at lower levels tend to be overlooked.

Thomson (1922) says of three species of introduced willows that one was planted in the Waikato basin before 1850; another was introduced to the Auckland Province about 1861; and a third was reported as established in Canterbury as early as 1879. He states that gorse and broom were sufficiently abundant by 1859 in Taranaki and Nelson to necessitate measures being taken for their control, and that in 1900 the tree lupin was listed as a noxious weed. There has been

both a wider dispersal and local development of these trees and shrubs since the times indicated by Thomson.

It is possible that the effects of the spread of introduced trees and shrubs on many environments of brown trout have been more significant than the effects of the reduction of the primitive vegetative covering. Except in lakes, in streams leaving them and in the few highland reaches of streams where gradient happens to be slight, the brown trout reaches its greatest abundance in the lowland reaches of streams in New Zealand. It is in lowland areas that the development of willows and other exotic plants has been greatest.

The planned planting and controlled growth of willows and shrubs may prevent lateral erosion and aid the transportation of detritus, water-borne from higher levels. Where, by confining flood waters, afforestation increases the weight and thrust of water on the river-bed, its effect is to render the bed less stable for trout to spawn in and less productive of food. Where flooding is neither frequent nor severe, the planting of stream banks, especially with willows, may have little effect on stream beds, but may greatly increase the amount of under-water cover for fishes and of vegetation above water in which terrestrial insects develop. Necessarily, the consequences of planting must usually be greater on small streams than on large rivers.

The uncontrolled spread of willows and of gorse, broom, and lupin along the banks and into the flood-beds of rivers and on to islands in their braided courses tends often to obstruct the passage of flood waters and, by increasing the precipitation of solids, to raise the levels of beds of rivers. The growth of willows in sluggish portions of the Mokau, Mangaokewa, and Waihou, in the Auckland Province, presented problems of flood control, and finally necessitated the removal of the trees. Willows have extended into and obstructed much of the course of the Inaha River in Taranaki and other streams in various parts of the country. The streams named are ones which had stable banks before willows flourished on them.

On the broad alluvial valleys and plains in Wellington, Marlborough, Westland, Canterbury, Otago, and Southland many rivers have open, eroded flood-beds. In reaches of moderate gradient many rivers flow against a line of willows on one bank or the other; gorse, broom, and lupin have developed extensively in flood-beds and on islands, often at greater distances inland than willows flourish.

It would appear that there are very diverse effects of this development of exotic trees and shrubs in the case of different waters and even in different parts of the same waters. The tendencies principally evident are:—

(1) In sluggish waters, to obstruct flow and increase the precipitation of silt and to aid the development of marginal swamps.

(2) In broader rivers lacking flood-beds, to confine flood waters and so to facilitate the transport of solids.

(3) In rivers with flood-beds, opposing influences are brought into play. Shrub growth in river-beds usually assists aggradation, and willows tend to offset this by confining waters and reducing lateral erosion.

Conditions in different waters vary too much to warrant assessment of the general results, for better or for worse, on trout fisheries through change in the suitability of steam-beds for invertebrate fauna. Certain effects, which have

occurred fairly generally, may be noted. There has been reduction in the accessibility of water to anglers involving, at the best, the provision of a reasonable amount of sanctuary water and, at the worst, so great a loss of access as substantially to prevent stocks from being exploited. There has been an increase in harbourage for tree-frequenting insects, although there is doubt as to the significance of such insects as trout food.

There has been an increase in the essential environmental factor of cover for trout and, possibly very much more significantly, of cover for eels. The cover requirements of trout, in many waters of sufficient size, may be met by depth of water alone. The nocturnal eel, however, requires either soft banks or detritus to burrow in or large boulders or logs under which to spend the daylight hours. In many waters there would appear to have been a tremendous increase through the introduction of willows in the amount of cover for eels, with possibilities of a consequent change in the relative abundance of eels and trout.

AQUATIC PLANTS

Conspicuous amongst introduced aquatic plants is watercress, which Thomson (1922) states was introduced soon after 1850 to Canterbury, where it developed with extraordinary rapidity and strength in the Avon. It has since almost disappeared from that stream, except as a margin-frequenting plant. It is now found very generally in spring streams in both islands, not only as a marginal plant, but in open, fairly fast-flowing water, and is often rooted at depths of over 4 ft. Commonly it harbours great quantities of pond-snails, chironomid larvae, and water-fleas (*Paracalliope-spp*), and, where the growth is dense enough, crayfish and eels. It can, however, so obstruct the flow as to intensify precipitation of fine detritus and thus lead to the loss of spawning ground for trout (Hobbs, 1937).

Canadian water-weed (*Elodea canadensis*), Thomson states, was introduced in 1868. Although now very widely spread, its development in streams has not been so general as that of watercress. It is, however, a common plant, and is especially abundant in association with a species of *Nitella* in silt beds in the Avon in Canterbury, where it was first established. The usually rapid character of New Zealand rivers over beds of boulders and gravels does not favour the development of aquatic plants, but *Elodea* is found on silt deposits in the lower reaches of many rivers, and has developed strongly among boulders in pools in the Kakanui River in North Otago, where weed-bed provides harbourage for eels.

DIVERSION OF WATERS

The diversion of waters for irrigation purposes, the draining of swamps, and the straightening of streams have altered the flow of many streams. Diversion of waters to irrigate lands and to water stock occurs on a moderate scale only as yet in the Canterbury and North and Central Otago districts of the South Island. In these relatively low rainfall areas, operations on the present scale would not influence fisheries adversely if water were taken only from major rivers, or if the practice of impounding flood waters for subsequent reticulation were adopted.

In areas where drought conditions are sometimes encountered and flow of surface water almost ceases in some streams, fisheries and agricultural interests may conflict sharply. In the Opihi River, a famous South Canterbury angling

stream, fully one-half of the surface-flowing water has been diverted for irrigation purposes during drought periods. This diversion race serves a number of farms. A substantial portion of the low-level flow was diverted from the Kakanui in North Otago to benefit a single landowner. No routine procedure has existed for according prior consideration to the conflict of interests which may arise in such cases.

In particular cases, where knowledge of the project and its possible effects have come to the notice of others concerned in time, concessions have sometimes been made. For instance, an electric barrier was erected on the Opihi diversion race; elsewhere fish passes (of questionable value) have been incorporated in dams. Substantial losses of smolts, such as occur in unscreened diversion races elsewhere, have rarely been reported in New Zealand.

The draining of swamps to increase the extent of pasture lands, the straightening of streams to reduce flooding, the ditching and draining of fields have proceeded steadily ever since trout were first established here. Such changes tend usually to reduce the total area of water capable of supporting life and to increase the rate of run-off. Generalization as to effects on stocks of trout are unsafe. As regards large streams, drainage works have usually affected marginal lowlands towards the river mouths, outside those parts of the catchment areas where precipitation is heaviest. Where this is so, drainage works may contribute but little to the instability of the bed of the river.

The draining of extensive marginal swamp lands along the lower Manawatu and lower Waikato in the North Island and, to a less extent, along the lower reaches of many other rivers has had the effect of reducing the extent of environment very suitable for inanga and eels. Any effects on trout have probably been indirect, and seem most likely to have arisen from changes in the quantitative relationship of stocks of trout, inanga, eels, and other forms of life. In general, shallow swamps do not provide a suitable environment for trout, but may be of importance to trout when they produce food or predators which find their way out of the swamps into streams frequented by trout.

The collection of surface water and its direction into channels may be beneficial to trout where the effect is to concentrate a sufficient body of flowing water to support trout. In the vicinities of Halswell and Springston, north from Lake Ellesmere in Canterbury, a network of drains picks up water from low-lying farm lands. At places such drains have been dug through soft ground to underlying shingle. Where this is so, spawning ground is provided for trout and is extensively used.

The straightening of sections of Waituna Creek in Southland accomplished much besides a substantial reduction in total length of the stream. A very sluggish and sinuous stream, with a silty bed growing much vegetation, became a more rapid stream with an increased extent of gravel bed, as dredging and more rapid flow removed fine matter off underlying gravels. Such increased shingle areas came, in a short time, to be used extensively by spawning trout. The work on Waituna Creek either destroyed or displaced quantities of eels. Thus a heavily eel-infested stream became for a time comparatively free of them, and chances of survival of trout fry were thereby enhanced.

In the Auckland Province, the removal of willows from streams to give improved

drainage has led, it is said, to sometimes striking local reductions in the density of eel stocks in portions of the Waihou, upper Waipa, and upper Mokau systems.

DAMS IN RIVERS

The flows of many streams have been impeded by the construction of dams, some of which do little more than to provide a step down which water flows, while others impound much water and form lakes above the obstruction. The use of direct water power has diminished as major hydro-electric schemes have come into operation. Here and there small water-driven mills have operated in recent years, for instance on the Avon in Canterbury and the Kakanui in North Otago. Many, however, of the small dams are residual from older power or water-reticulation works. Streams so affected include the Hollyburn in Southland, the Shag and Waianakarua in North Otago, the Kaupokonui in Taranaki.

Dams are harmful where they hinder the free passage of trout to spawning grounds or cause abnormal congestion on such grounds as exist below them. Those in streams mentioned include some which become accessible to trout during floods. However, eels can travel up or round all these obstacles at practically all times. Thus they favour the easy dispersal of eels rather than of trout throughout the length of the streams.

At Maheno, on the Kakanui, a dam diverts water to a mill race. The base of the dam is permeable. Water which escapes below it would be sufficient to enable trout to pass up if the dam were sealed and the water directed over the top at one point. In 1937 approximately one-third of the total spawning redds found in 20 miles of the Kakanui River were in a short portion of the race below the mill. While the construction of this race provided increased spawning ground for trout, the dam and race prevent the dispersal of spawners, with the result that excessive spawning takes place in a restricted area.

Large dams constructed in streams mainly for hydro-electric purposes effect significant changes, besides extending the area capable of holding trout and possibly increasing the food resources on which trout depend. The very process which increases the extent of the environment often reduces the extent of the spawning grounds. Where this happens, even fewer trout are produced to stock the larger area of lake water than were produced previously to stock the portion of stream affected. This was the case when Arapuni Lake was formed in the Waikato River (Hobbs, 1940). In addition, as a consequence of the construction of this particular dam, eels gained access to water previously inaccessible to them. Conversely, and more usually, the construction of dams may deny eels access to upper waters of rivers.

The extensive lake above Waipori Dam is one of several eel-free artificial lakes in Otago which provide good fishing. It would appear that in some cases absence of this predator more than compensates for reduction of spawning ground.

Publicity given in the British Isles and the United States to the desirability of having fish passes on dams in salmon rivers is sometimes reflected in New Zealand by a demand for the construction of passes. What may be necessary under conditions obtaining abroad may be harmful rather than otherwise under the different conditions existing here. Eels populate such portions of river systems as are accessible to them from the sea. Trout disperse through river systems usually

downwards from their spawning areas. Thus a natural fall or artificial dam, impassable to both eels and trout, may permit eels to exist only below it and trout both above and below.

Eels in New Zealand, because of their abundance and great size, present a problem not encountered in the British Isles and North America. Eel-less waters such as Lake Taupo and portions of the Waihou system (Hobbs, 1940) and Lake Rotorua and Rotoiti, which contain very few eels (probably transplanted there by Maoris), are remarkable for the density attained by stocks of trout. Consideration of these facts led the Grey District Acclimatization Society to close, in 1938, an efficient fish ladder on the Kaimata Dam on the Arnold River. This was done in the hope that maturing eels in the extensive water system above the dam would in time migrate down over the dam and that they would not be replaced by young stock working upstream. As small eels can climb even vertical wet concrete walls, their exclusion from waters above dams or falls is difficult, where the flow is variable. Eels lack the ability of trout to swim against some rapid currents. Their passage will be stopped—for instance, at Okoroire, on the Waihou—if they cannot climb round.

POLLUTION OF RIVERS

Because of the great abundance of streams in New Zealand, because of their usual steep gradients, and because the country is not yet heavily populated or highly industrialized, pollution has not yet caused substantial and widespread deterioration of fisheries.

The cities and most major towns in which secondary industries are grouped are on the sea-coast. Thus a big proportion of sewage and many trade wastes likely to cause pollution drain direct to sea and not into trout waters. In a few cases where rivers flow through closely-settled industrial areas, as in the Hutt Valley, or in Christchurch, drained by the sluggish Avon and Heathcote Rivers, or again at Hamilton and the growing industrial areas below it on the slacker reaches of the Waikato, there is a growing menace to fisheries from pollution of a variety of kinds.

More generally through the country, pollution arises or threatens from a fairly restricted range of industries—notably mining, sawmilling, and flax processing and the various types engaged in the processing of the products of pastoral industries. Significant are the cheese, casein, and butter industries, with a multiplicity of widely-scattered units, the frozen-meat industry, with a smaller number of very large units and the dispersed plants of the wool-scouring and hide-treating industries. Evidence of direct harm to fisheries from these sources is often less obvious than the reduction of the attractiveness of waters to anglers and others arising from the entry of foul-smelling or unsightly wastes. **Where, however, pollution develops progressively over a long period, it may render a stream progressively less suitable for trout, without necessarily advertising the harm it does by any sudden large-scale destruction of fish.**

The pollution laws are both obsolete and inherently partial in that they permit the discharge of mining wastes into 161 proclaimed sludge channels, principally in Westland and Otago; they provide penalties, without requiring proof of harm, for the discharge of sawmill and flaxmill refuse, lime, or sheep-dip, but in the case of other substances, the law requires proof that they are actually harmful.

The existing laws, which are a survival from the pioneering era, have proved inadequate to prevent the discharge of wastes from many newer types of industry and older types which have expanded greatly in the last 50 years.

SUMMARY

To conclude this statement on changes in the physical background, it may be said that man's interference with streams and their drainage areas began before trout were introduced, and has continued and become very widespread since then. Interference has been of many kinds. Where changes have been made gradually in the surface and in the vegetative covering of catchment areas, absence of earlier detailed description makes it difficult to-day to distinguish the results on streams from natural developmental processes. The effects of more sudden and direct alterations made in river systems are more readily apparent.

Locally there have been significant changes involving increase or reduction of the dimensions of environments, but, generally, there is much the same total area of lake and stream water as formerly.

Qualitatively, environments have become less suitable for trout, most certainly where pollution has occurred and, again, where the vegetative covering of steep portions of catchment areas has been reduced. The draining of swamps and ditching of low-lying land, the straightening of streams, the construction of dams, and the development of exotic trees and shrubs have had effects which in some cases are beneficial and which in others are harmful to trout.

Although many environments have changed—sometimes for better, possibly more often for worse—**there is no evidence which suggests that through the country generally in the last sixty years there has been any progressive deterioration in the capacity of most waters to produce trout.** Nevertheless, environments are not stable in character, and it is against a background of change, which here and there may have had significant effects, that any changes in the composition of stocks of trout should be reviewed.

II.—Changes in Size and Abundance of Trout

PAST AND PRESENT STATUS OF STOCKS OF TROUT

The belief that in most parts of the country there has been significant depreciation in the numbers or sizes of trout is more easily encountered than is the evidence to warrant such a belief. No data exist which permit of thoroughly sound qualitative and quantitative comparisons being made of the stock of trout in any particular water with the stock which existed there from 40 to 70 years ago.

The individual angler tends to base his views on the question of depreciation on personal experiences or on a comparison of results of his own efforts with reports of earlier efforts of others. He is not necessarily interested in the question of whether the total yield to *all* anglers is as great as formerly. He is, however, aware of certain effects of the increase in the number of anglers. He knows that, with the increased number of anglers about, a particular fish, or a series of fish, which he hopes to catch may be taken by other anglers before he himself has opportunity. He knows, too, that the prior occupation by other anglers of his favourite piece of water may compel him to waste good fishing time travelling to

other and less favoured waters. Again, especially on small streams, mere disturbance of the water by another angler fishing ahead of him may lessen his chances of success, whether or not the other angler catches the fish. These two latter effects, by lessening the success of the individual, may contribute to his dissatisfaction and create a loose impression of depreciation of stocks, whereas actually the deterioration is in conditions formerly favourable to the individual angler.

Arthur (1878, 1881, and 1883) anticipated that the day would come when information would be sought as to past conditions of the fisheries, and he set down a mass of facts in regard to acclimatization and early development of stocks. His records relate mainly to Otago. Useful as these papers are in other respects, they include little data on size of typical fish for different waters. Later, Spackman (1892), in a popular handbook, recorded further captures of fish, but inclined in some cases to record the exceptional rather than the typical. More than 600 annual reports of Acclimatization Societies and Government Departments have been searched for data. Very rarely are they found to include facts useful as an index of the state of stocks at any period. Much space is devoted to rather meaningless statements that streams are fishing well or badly, or are improving or going back. Records of actual results for a stated amount of angling effort are rare.

Phillips (1929 and 1931) offered no evidence of deterioration of stocks of trout in the Wellington District, but studied general conditions affecting their well-being there.

Percival (1932) studied the depreciation of the stock of trout in the Oreti River in Southland, and produced evidence from an angler's diary which is re-presented later in this section.

Through the co-operation of individual anglers, angling clubs, and acclimatization societies, additional data relating to many waters in the southern portion of the North Island and in the eastern and southern provinces of the South Island have been made available. Evidence is mainly of size of trout at different times during the last 65 years. In addition, certain data permit of comparisons being made of the past and present angling quality of waters, as measured by results obtained from like efforts. The inadequacy of earlier published data is such that, for record purposes, facts, possibly useful at some future time, are included in this section, although in certain cases they are too meagre to be of immediate use.

EARLIER EVIDENCE OF DETERIORATION

Published evidence of early changes in the size and abundance of trout is limited to some of the waters of Otago and Southland. Brown trout were first released in these streams from 1869 onwards. Arthur (1883), who was a keen contemporary observer, offered only limited evidence of depreciation and this from a very few small streams. At a time when scale-reading was unknown, he stressed the need for checking the rate of growth of trout by marking and recapturing trout. "Until this can be done," he stated, "we are constrained to appeal to such approximations as may be got from the average weight of fish per day taken by anglers each year. From one angler's diary I can give this: only, however, as regards the Lee and Deep Streams."

Arthur (1881) describes both these streams as being "full of trout," but referred, even at so early a date, to lean and emaciated male trout taken "some

years ago" from the Lee. In 1883 he states of trout in these two streams: "Anglers and shags have fished them incessantly; hence their disappearance to a great extent. Both streams have also been much polluted at times by gold-mining." Yet the diary records he produces show that from the period 1875–8 to 1878–83 the average weight increased in the case of the Lee from 1.25 to 1.52 lb. and in Deep Stream from 1.20 to 1.86 lb. However, the catch per angler per day fell from 2.67 to 1.50 fish in the Lee and from 3.66 to 2.56 in Deep Stream. It will be observed that these are the best data which Arthur offers in support of alleged depreciation. As the sales of angling licences increased by approximately ten times between 1874–5 and 1883–4, these data afford no evidence of depreciation of stock even in numbers, for there were more anglers to share the catch.

The Water of Leith flows through Dunedin City. Arthur says: "Fished every day by dozens of anglers, so small a stream, possessing such indifferent cover is bound to suffer." Twenty trout taken from the Water of Leith in the opening season, 1873, totalled 13 lb. in weight. Some years later Spackman (1892) held that a fish of 1 lb. was a prize, unexpected except when sea-run fish of 3 to 5 lb. entered. In 1944–6, 397 trout taken averaged 0.97 lb.; one angler averaged 4.5 fish per trip in 86 outings. These fish included very few maturing sea-run fish; the average catch is remarkable for a very small stream flowing through a city.

The Waitati, small and handy to Dunedin, is described as having fallen off in productiveness. The stock of the Kuriwao is stated to have been reduced by poaching and excessive fishing. The five streams mentioned so far are very small. Trout in the Shag River, which is an important angling water, are described as still fairly plentiful but not quite as large as formerly. Eighteen other waters, which include major angling streams, are discussed without reference to deterioration of stocks.

In 1883 (the same year as Arthur's survey) the administrative bodies concerned with those southern districts are quoted by Sherrin (1886) as saying: "Our experience is that in many streams the stock of trout has not succeeded well of late years. . . . Where they were numerous and large a few years ago, they have diminished to an alarming extent." Some suspicion of exaggeration and special pleading must attach to this statement. It forms part of a protest to the Government against the fixing of the licence fee at 5/-, an amount which the societies claimed would permit everyone to fish and which would not provide adequate funds to cope with the difficulties of maintaining stocks. Acceptance of the more specific statements of Arthur is preferable.

Spackman (1892) reviewed angling conditions in many waters in both islands, but speaks of a progressive deterioration in size and number of trout in none. He mentions again the little Leith as being full of trout of small size with larger fish of 3 to 5 lb. present only after freshes induced their entry from the sea. He quotes a reliable source for the view that a dozen and a half rods were often present where 17 years before two might have been found. He speaks of the drought conditions in Canterbury in 1889 and 1890 permitting the poaching of most of the large trout in the Selwyn, but expresses confidence in the early recovery of the stock. In one other case—the Otamita, tributary to the Mataura—he records the capture of 120 trout averaging over 4 lb. in weight in some earlier year. Under the drought conditions of summer 1889–90 poaching and angling

almost cleared the stream of large trout. There is no evidence that a recovery of the former high average weight ever eventuated; to-day it is about 1 lb.

It will be observed that the published evidence of depreciation before 1895 is very limited—much too limited to provide any valid ground for the present widespread belief that stocks have deteriorated in numbers or in size of components since shortly after trout became established. Belief in depreciation is therefore probably based either on a comparison of present day catches with those recorded by Arthur (1883) and Spackman (1892), or on recollections of anglers whose experiences, in very few cases, could extend back to last century. For the moment we are concerned only with the published evidence, and that of Spackman is greatly more comprehensive than that of Arthur. Spackman's evidence of size is not always acceptable, for often he records the exceptional rather than the typical catch or he indicates the range of sizes of fish taken without giving any indication of average weight. Where average weight is given unsupported by data, it cannot always (as will be shown) be accepted as reliable.

From the mouth of the Rangitata for the season 1891-2, Spackman records the capture of 190 trout of an average weight of 7.19 lb. The season itself may have been exceptional or outstanding bags may have been selected. Records used in this paper relate to all fish taken by two anglers in the Rangitata from 1890 to 1900. They show an average weight of 3.42 lb. for 762 fish. Of these, 184 (taken at the mouth of the river) averaged 4.42 lb. In the Shag River, Spackman states that trout average 3 lb. to 4 lb. in the lower reaches and about 2 lb. higher up. Records produced here for the first time show an average weight of 1.17 lb. for 654 trout in the 1880's and 1.14 lb. for 192 fish in the next decade.

The allegation that depreciation of stocks has taken place is vague in form and indefinite in time. In some cases it relates to size of fish and in others to numbers. Where it relates to size, there is often an accompanying belief that greater numbers of small fish have replaced a smaller number of large fish, and that fish no longer grow as rapidly as they formerly did.

Percival (1932) studied an alleged depreciation of stock in the Oreti River. His basic evidence consisted of diary records of one angler who had fished a restricted length of the river over many years. It was shown clearly that a progressive reduction in average size of trout had continued from the late 1880's until the 1920's. No evidence was offered as to change in numbers of fish.

As regards rate of growth of fish, Percival showed that in recent years trout had grown as fast as certain trout had within the first ten years of their establishment in New Zealand. As this comparison was of growth, largely of exceptional trout in Arthur's time, with growth of fish from other waters, which at later times were also exceptional, it cannot be regarded as wholly satisfactory. Arthur's papers provide, unfortunately, no adequate evidence of how the typical fish of any water grew in the early days. No survey was made and recorded of the extent of food resources when trout were first introduced.

Percival, 60 years later, showed that food organisms in great quantities could still be found, even in water supporting large stocks of trout. Percival found evidence, other than of change of growth, sufficient to account for the diminution in size of fish in the Oreti. He showed that there had been a very great increase in the intensity and mobility of the angling effort and that in readily accessible

Oreti River—Southland (Sth. Is.) between Dipton and Benmore, where the late Neil McKay recorded his captures of over 19,000 brown trout during 35 angling seasons and thereby provided the best data on the history of a stock of trout so far available in New Zealand. The river has a very braided course and trout spawn largely in more stable side channels. Much of its course is through erodible flood plain. In winter most spawning takes place and in summer also the concentration of trout is greatest in reaches where the over-all gradient is less than 15–17 feet per mile. (Plate I.)

Mataura River—Southland, Otago (Sth. Is.)—a very prolific brown trout river which, for many years, was discoloured by debris from gold mining. Much of one formerly useful nursery stream —the Waikaka—has been rendered useless to trout by the change of character of bed resulting from entry of mining wastes.

The Mataura system includes the Mimihau and Wyndham Rivers, both relatively stable and highly productive of brown trout, with moderately well-known angling histories. (Plate II.)

Pomahaka River—tributary of the great Clutha River in Otago (Sth. Is.). Analyses of diary records suggest that the Pomahaka may have yielded, in the early nineteen thirties, as much as one-third of the estimated annual catch of 200,000 trout of Otago's 2,264 anglers. (Plate III.)

Shag River—Otago (Sth. Is.). The recording of captures by angling clubs has offered valuable historical data on the brown trout fishery of this river. The weir shown is obsolete. Although it adds to the beauty of the landscape, it prevents the free access of trout to spawning grounds except during floods. (Plate IV.)

reaches of the Oreti the fish were of low average size, apparently because they were caught before they had a chance of becoming old and large. It will be noted that this conclusion, applied for the first time to a major angling river, was in accord with what Arthur and Spackman had found much earlier in smaller streams.

MIGRATION

Anglers' impressions of stocks are based only on such fish as they catch and see during the angling season. Arthur (1883) says: "Migration appears to be the refuge of trout in Otago when planted in a stream deficient in size and range of water and of food. Hence the disappearance of the largest trout from the Water of Leith, except during the spawning season. They evidently resort to the salt water of Otago Harbour."

There is to-day abundant evidence of the presence of trout in coastal waters of the South Island, especially along the south and east coasts. Evidence of occurrences in North Island coastal waters is meagre, but exists in the case of the Wellington, Taranaki, and Hawke's Bay Provinces. Spackman (1892) referred to the capture of a trout in the graving-dock at Lyttelton Harbour in 1891, many miles from the nearest river. They sometimes travel great distances from streams in which they spawn. A spent fish, marked in the Selwyn River in June, 1931, was recaptured the following February 16 miles up the Rangitata, which enters the sea 50 miles south from the outlet of Lake Ellesmere, into which the Selwyn drains.

It is a matter of common observation that large numbers of trout are taken as they enter from the sea such rivers as the Waiau in Southland and the Waitaki, Opihi, Rangitata, Ashburton, and Rakaia in Canterbury. These are large rivers to which Arthur's description as regards size and range of water cannot apply. It is clear from Spackman that fish were behaving this way before 1892.

The view of Hope (1927) is that whitebait (larval *G. attenuatus*) formerly entered all rivers in greater numbers and ascended to the headwaters, grew into adults, and descended in winter to spawn. Trout, he states, were thereby induced to enter from the sea early in the angling season and to remain upstream accessible to anglers throughout the season. He states further that, with a decline in numbers of whitebait, trout fed more on smelts (*Retropinna spp.*), which do not ascend much above the influence of the tides. They follow the smelts in from the sea and return to the sea when the smelts, having spawned, drop downstream.

As against this view may be considered the better specified observations of Arthur (1883). Arthur mentions whitebait in the lower waters of the Shag River and in pools near the mouth of the Leith, but records their presence nowhere near the headwaters of streams and rarely away from coastal waters. The exception is the Pomahaka, large and quiet-flowing tributary of the Clutha. The restriction of range then to more quietly-flowing coastal sections of streams, with extensions farther inland only in quiet-flowing and relatively stable streams, agrees with present-day observations.

Although Hope's description of former distribution cannot be accepted, it is probable that fewer whitebait now enter many waters, and that of such as do enter man nets relatively more and the trout gets less than formerly. It is agreed

with Hope that some trout follow whitebait and smelts in from the sea, thus bringing them within reach of the angler. It is the experience of many anglers at the mouths of large east and south coast rivers that trout enter in substantial numbers during the angling season only when whitebait or smelts are running. The Water of Leith offers evidence that a stock of large mature trout may exist in the sea and that few components of it come into fresh water except in the spawning season. Therefore, in considering certain of these fisheries, it is necessary to keep in mind the possibility of changes over the years in the proportion of the stock frequenting fresh and salt water. To such an extent as the inducement of fish to come within range of the angler has lessened, there may appear to have been a deterioration of a stock.

SELECTION AND PRESENTATION OF DATA

New evidence is available which goes some way towards showing to what extent the average size of trout has been maintained in a series of important angling waters since, in some cases, a few years after streams were first opened to angling. This evidence is taken largely from diaries of anglers and official records of trout weighed in in contests conducted by angling clubs. It is amplified by the inclusion of data from Arthur and Spackman, where it appears that typical rather than exceptional catches have been recorded, and where such data are sufficiently specific as to locality of capture, or lure employed, to warrant comparison with data equally well described from some later period.

Except at Lake Taupo, where there are mainly rainbow, data relate solely to brown trout,. the only important exotic species found in all waters under consideration. Perch are present in small numbers in some of the waters. Quinnat salmon (*O. tschawytscha*) are present in substantial quantities in the Rangitata and in less quantities in the Opihi and Ashburton Rivers. Trout enter these three rivers from the sea. Salmon became established in the Rangitata between 1910 and 1920 and in the Opihi and Ashburton in the following ten years.

Comparisons of the results obtained by anglers at different periods are satisfactory only if the methods used were not such as tended to select fish of different sizes and if the localities fished in a river were not different ones which at any time would have yielded fish of different sizes. Professor Percival has made available for re-examination the data he used from the Oreti River. There, in the 1880's, fish were taken by the same angler in the same reach. Those taken on artificial fly averaged 1.04 lb. and those on artificial minnow 2.51 lb. This angler, as so many did, began as a minnow fisherman and finished as a fly fisherman. Undifferential results of his angling at different periods would not give a true picture of changes in size of trout.

Data from the Locky River in the same period show an average weight of 1.45 lb. for 139 fish taken with artificial fly and 3.07 lb. for 145 taken with cicadas and grasshoppers. In many other waters, the nature of the lure, as is shown in Table I, makes little, if any, difference.

TABLE I

River	Lure	No. of Trout	Average weight in lb.
Waipahi	Artificial fly	546	1.05
,,	Any legal lure, including artificial fly	313	0.92
Shag	Artificial fly	201	0.69
,,	Any legal lure, including artificial fly	284	0.67
Pomahaka	Artificial fly	66	1.00
,,	Any legal lure, including artificial fly	53	1.00
Wainui-o-mata	Artificial fly	2916	1.22
,,	Artificial minnow and natural baits	700	1.22
Manawatu	Artificial fly	75	1.85
,,	Artificial minnow	71	1.69

Trout are more uniform in size throughout the length of some streams than in others. Most commonly the average size is greater near tidal water than higher up. The Hutt River shows an average weight of 2.49 lb. for 111 trout taken with artificial minnow and natural baits in and near tidal water. Higher up, 110 fish taken with the same lures averaged 1.71 lb. In the Rangitata, fish taken at the mouth averaged 4.42 lb. as against 2.53 lb. for a substantial sample taken with the same lures 15 miles up the stream. Often accessible middle reaches of a river hold smaller fish than are found nearer to the headwaters. In the Hutt, 111 trout caught with artificial fly between tidal water and the entrance of the Akatarawa averaged 1.01 lb. as against 1.65 lb., the average shown by 506 taken in the same way above the Akatarawa. A very striking difference is shown between fish taken with artificial fly from different reaches of the Oreti. There 131 from the plains section averaged 0.79 lb. against 4.84 lb. for 53 taken in the lower portion of the gorge and 5.80 lb. for 20 taken above the gorge.

In some cases certain lures used in restricted localities at certain times will take fish greatly larger than usual. One angler, fishing by day with small artificial flies, took 2977 trout which averaged 0.85 lb. in weight in the Opihi River. At dusk and after dark, small artificial flies took fish which averaged 0.99 lb. in weight. Yet, when the same angler fished after dark with artificial minnow and with large salmon flies in Burke's Pool, a short distance up from the sea, he took 207 fish which averaged 6.06 lb. and included many individuals of more than 10 lb. Where selection of data has been practised, it has been done in order to limit comparisons to results obtained under like conditions.

Alterations of minimum-size limits could affect the average weight of fish taken by anglers. In districts from which data will be considered, the size limit was nine inches for most of the period with which we are concerned. Especially following the publication in 1932 of Professor Percival's study of depreciation in the Oreti, most districts sought to offset effects of increased intensity of angling by increasing the minimum-size limit and by reducing the permitted daily catch per angler. A 10-inch limit was introduced in the latest case by 1937. This remains the limit in Otago, Southland, and Mid-Canterbury. Later, it was raised to 11 inches in Southland, North Canterbury, and Wellington.

In certain rivers these changes had little effect. For instance, in the Manawatu, with a minimum size of 11 inches, under-sized fish comprised only 7.5 per cent.

of 440 trout taken in 1940-2. Where, however, the average size of fish caught is lower, the proportion of under-sized fish may be more significant. The low average size of 12.56 inches was shown by 300 trout from the Opihi after the size limit had been raised to 10 inches. The numbers of fish falling into successive inch grouping from 10 to 18 inches were 50, 103, 88, 38, 10, 5, 3, 2, 1. The figures suggest that fish of nine inches would have been less numerous in catches than those of 10 inches. However, even had they been as numerous, the inclusion of 50 (averaging 9½ inches and 6 oz.) would have depressed the average weight of the whole sample only from 0.66 lb. to 0.62 lb.

SIZE OF TROUT IN SUCCESSIVE DECADES

In Tables II, III, and IV are presented data from 19 streams and one lake on the size of trout in different periods between 1880 and 1945. The 19 streams comprise portions of 12 separate river systems. In three cases data relate to restricted reaches; in the Oreti, to the Dipton–Benmore portion; in the Hutt, from the Akatarawa down; in the Manawatu, to the Woodville–Kumeroa portion. Data from the Rangitata are included, subject to reservations. A great variation in average size of fish from season to season is shown only by data from the Rangitata—a variation sufficient to invalidate the drawing of any conclusions as to long-term changes of size of the stock. It is possible that, if more extensive records were available of fish taken with minnow in the lower reaches of the Ashburton and the Hutt Rivers, a substantial variation might be shown in these cases also.

In the Rangitata, samples for the first decade which give an average of 2.10 lb. were all taken in one season. All seasons of the following decade are represented, and the variation from season to season was from 2.71 lb. to 4.67 lb. In the third period, six seasons were represented, and the variation was from 3.75 lb. to 4.67 lb. In the fourth decade, an average of 1.96 lb. is based on records for one season only. The final period comprises samples taken in three seasons, and the range of average size was from 2.20 lb. to 3.79 lb. It should not be deduced that the rate of growth or the average size of the stock as a whole rose and fell in the surprising ways the figures might suggest. Rather would it appear that portions of the stock differing in dominant size groups entered from the sea in different years during that part of the year when anglers are able to fish.

Average weights in pounds are given for fish from all streams except the Selwyn. There averages are of lengths in inches of mature females taken during spawning runs.

Numbers of fish comprising each sample are shown in parentheses.

TABLE II

SIZE OF TROUT IN SUCCESSIVE DECADES

South Island

(Weight in lb. Numbers of fish comprising samples are shown in parentheses.)

	SOUTHLAND				SOUTH OTAGO			
River	Aparima	Oreti	Oreti	Otapiri	Wyndham	Mimihau	Pomahaka	Waipahi
Lure	A.F.	A.M.	A.F.	A.F.	M.L.	M.L.	M.L.	M.L.
Period								
1880–1890	.....	2.51 (238)	1.04 (173)	.....	.....	.....	1.75 (135)	2.33 (193)
1890–1900	0.89 (106)	1.64 (312)	0.93 (2992)	1.02 (233)	.....	.....	.....	1.33 (527)
1900–1910	0.61 (30)	.....	0.89 (8411)	1.11 (18)	.....	.....	.....	1.05 (489)
1910–1920	.....	.....	0.71 (5275)	1.07 (30)	1.06 (163)	0.86 (314)	.....	1.11 (209)
1920–1930	0.65 (72)	.....	0.62 (4345)	.....	.....	0.90 (142)	.....	1.05 (64)
1939–1940	0.95 (157)	.....	0.79 (131)	1.07 (210)	1.09 (140)	1.11 (273)	1.38 (294)	1.04 (512)
1940–1945	.....	.....	.....	.....	1.64 (376)	1.09 (213)	1.36 (226)	1.58 (190)

(A.F. = Artificial Fly. A.M. = Artificial Minnow. M.L. = Mixed Lures.)

TABLE III

SIZE OF TROUT IN SUCCESSIVE DECADES

South Island

(Weight in lb. Numbers of fish comprising samples are shown in parentheses.)

	NORTH OTAGO			CANTERBURY			
River	Shag	Opihi	Temuka	Rangitata	Ashburton	Ashburton	Selwyn
Lure	M.L.	A.F.	A.F.	M.L.	A.M.	A.F.	Trapped
Period							females.
1880–1890	1.17 (654)	.....	1.18 (436)	2.10 (97)	1.99 (363)	.....	(Length
1890–1900	1.14 (192)	0.88 (1912)	0.70 (614)	3.42 (762)	1.59 (509)	0.52 (458)	in inches)
1900–1910	0.79 (160)	0.86 (3647)	0.71 (589)	3.56 (616)	1.60 (56)	0.60 (419)	
1910–1920	0.86 (112)	1.05 (111)	.....	1.96 (55)	.....	.....	20.2 (473)
1920–1930	.....	.....	.....	.....	.....	.....	18.9 (594)
1930–1940	0.70 (550)	0.68 (345)	0.83 (136)	2.90 (1329)	.....	0.85 (92)	19.3 (2162)
1940–1945	1.36 (288)	0.95 (22)	0.68 (258)	.....	.....	.....	19.1 (416)

(A.F. = Artificial Fly. A.M. = Artificial Minnow. M.L. = Mixed Lures.)

Attention is directed firstly to the period 1880-1900, for which data are given in Tables II and III for six rivers—the Oreti, Waipahi, Shag, Temuka, Rangitata, and Ashburton. In four of these, all represented by substantial samples—namely, the Oreti, Waipahi, Temuka, and Ashburton—significant falls in average size are shown. Little change is shown in the Shag. Where there is good evidence, it is of depreciation rather than of a well-maintained average size.

From 1890 onwards, the Oreti alone provides evidence of long-continuing depreciation; in this case it extended into the 1920's. The Pomahaka shows a fall in size, which in the case of its tributary, the Waipahi, was arrested before 1910. In the Shag also there was a drop in size at about the turn of the century. Although depressed periods are sometimes shown later, there is no clear evidence of progressive depreciation after 1890 in the Aparima, Otapiri, Opihi, Temuka, or Ashburton. Data from the Wyndham, Mimihau, and Selwyn are available only from 1910 onwards. No downward trend is shown in these cases.

A few more fragmentary records may be added to the foregoing. An early record from the Mimihau is of the capture, with fly, in 1896, of 71 trout weighing 130 lb. This is the aggregate of three selected bags, but whether they were chosen because of the number or the size of the fish comprising them is not stated. The numbers are not outstanding by more recent standards; the size is. The *Lyttelton Times* of 20th December, 1882, records an "extraordinary take of 10 fish of a total weight of 40¼ lb." in the Selwyn. Such a catch would not be remarkable to-day. In the Lee, where Arthur (1883) gave 1.25 lb. as the average weight from 1875 to 1878 and 1.52 lb. for the years from 1878 to 1883, a small sample of 36 fish in the 1930's averaged 1.04 lb. The Waiwera yielded 33 fish averaging 2.01 lb. in the seasons 1879–83. Between 1935 and 1945, 143 trout averaged only 1.24 lb. From the Omarama, first stocked in 1875, Arthur (1883) records the capture of 19 fish, four years after, of 2.14 lb. in average weight. This small stream in 1940 yielded 16 fish averaging 2.51 lb. The Waitaki is a major river, of which the Omarama is a tributary. It was first stocked in 1869. Spackman (1892) records that 10 years later 22 trout taken there averaged 1.06 lb.; the heaviest individual was 5.75 lb. In 1890–91, 169 trout averaged 6.64 lb.; the heaviest was 14 lb. One hundred trout taken about 1940, probably farther upstream, averaged 3.38 lb. and included one of 16 lb. The weight of sea-run trout at the mouth of the Waitaki and other rivers varies substantially, often during one angling season. These data are not sufficient to indicate long-term changes in size.

The evidence from South Island waters is not of general depreciation in size; nor is it of continuing depreciation. Where evidence of depreciation is found, in most cases it is of depreciation appreciable in extent but restricted in point of time to the years preceding, in some cases, 1900, and in others, 1910, and in only one case certainly continuing later than that. In a few cases there is a suggestion of a further depression of average weights in the 1930's and early 1940's. Yet fluctuations shown earlier in these waters suggest the inadvisability of attaching too much significance to them. There is little in the present evidence to suggest

that anglers of the present day, who have in past years fished a series of these streams, would have noticed any progressive deterioration in size of trout. The question of changes in numbers will be considered later.

CHANGE IN SIZE OF TROUT—NORTH ISLAND

Suitable records presented in Table IV are available from the central portion and from the southern half of the North Island. Of the six streams represented, the Mangaroa is a tributary of the Hutt; the Makakahi and Oroua enter the Manawatu. The Wainui-o-mata and Hutt are the two trout rivers nearest to Wellington city. The Manawatu system is of great extent, and provides most of the angling readily available from Palmerston North, on the western side of the Ruahine Range, and from south of Eketahuna to north of Dannevirke on the eastern side. Between them, these river systems contribute a substantial proportion of the brown-trout fishing available in the North Island. Although fish from the Manawatu and Makakahi are shown as having been taken with an assortment of lures, in all periods most were taken with artificial fly, a method which was shown earlier in the case of the Manawatu to give results comparable in size with results obtained from the use of minnow. Little, if any, angling was done before 1885 in the Wainui-o-mata and Hutt, and it was onwards from 1890 that the Manawatu was recognized as a productive water.

TABLE IV

SIZE OF TROUT IN SUCCESSIVE DECADES

North Island

(Weight in lb. Numbers of fish comprising samples are shown in parentheses.)

River	Wainui-o-mata	Hutt	Hutt	Mangaroa	Manawatu	Makakahi	Oroua	L. Taupo
Lure	M.L.	A.M.	A.F.	A.F.	M.L.	M.L.	M.L.	M.L.
Period								
1880–1890	1.02 (34)	1.39 (18)	0.65 (59)	.....	.....	.....	.....	.....
1890–1900	1.30 (2525)	0.98 (27)	0.97 (81)	0.67 (89)	1.83 (144)	1.30 (113)	1.21 (71)	.....
1900–1910	1.10 (656)	1.92 (73)	0.89 (13)	.....	1.84 (143)	1.05 (11)	.....	6.52 (376)
1910–1920	1.15 (293)	1.83 (42)	.....	.....	.....	.....	.....	4.41 (3059)
1920–1930	1.36 (76)	.....	1.37 (102)	.....	.....	.....	.....	6.14 (9091)
1930–1940	1.13 (66)	2.10 (221)	1.01 (103)	1.52 (218)	2.18 (34)	.....	1.33 (176)	4.96 (6273)
1940–1945	.....	.....	0.97 (9)	1.27 (62)	1.99 (190)	2.90 (318)	.....	5.33 (9336)

(A.F. = Artificial Fly. A.M. = Artificial Minnow. M.L. = Mixed Lures.)

These rivers, in contrast with many waters in the South Island, provide no evidence of having carried fish of a greater average size than they hold to-day. Records of captures from the Wainui-o-mata indicate that, over a long period, average size, despite small fluctuations, has been well maintained. The three sets of data relating to the Hutt and its tributary, the Mangaroa, include many small samples. Yet, separately and collectively, these sets of data suggest that size has been greater this century than it was about twenty years after the introduction of trout. However, data from the Hutt itself relate to seasons beginning with 1887-8. There is evidence of a very much greater average size of trout in 1885-6 and 1886-7, the first two angling seasons. Then 130 trout, captured with unspecified lures, had the high average weight of 6.76 lb. The case is an extraordinary one, because it is the only one of the North Island rivers where a reduction of size is shown. However, in 1945-6, some very good catches were made, including one of twelve fish averaging 5½ lb., taken on minnow in the lower reaches. In the Hutt, as in southern rivers, it would appear that angling is much influenced by sea-run fish, which in different seasons vary in quantity and size. The history of the Hutt is discussed further in Appendix E.

In the Manawatu system, the size of fish in the principal stream and in the Oroua has been much the same in the last fifteen years as it was when angling began, and, in so far as change is shown, it is favourable. The Makakahi now shows an average size of nearly double that evidenced in the 1890's.

Lake Taupo is the only water where the local administrative authority has kept records of size of fish. Much of the material for the last two and a half decades was recorded by the Department of Internal Affairs.

The grouping of Taupo data in decades tends to hide some remarkable changes in average size of rainbow trout. The full data show an average weight of 6.5 lb. in 1908–09, a rise to 8.5 lb. in 1910–11, a period of depressed weights of usually between 3 lb. and 4.25 lb. from 1915 to 1920, a fairly sudden climb to 10.8 lb. in 1923–24, and thereafter a sharp fall and fluctuations in subsequent seasons, usually between 4.5 lb. and 6.5 lb. In the five seasons to 1944–45, the average weight was rather better than in the previous ten years.

RELATIVE ABUNDANCE IN DIFFERENT PERIODS

An angler's interest in a stock is in the numbers as much as in the size of fish comprising it. Within limits, a decrease in average size of fish, such as has occurred in certain waters of the South Island, will not greatly affect the value of a fishery if there has been a compensating increase in numbers. Evidence of a well-maintained satisfactory size of fish in certain North Island waters is only reassuring if fish of such sizes are still reasonably abundant.

The only available measure of relative abundance of trout in past and present times is that obtained from a consideration of results of angling efforts of like intensity and duration in past and present times. Ideally, data for this purpose should comprise results obtained by employment of the same angling methods, by anglers of like skill, fishing the same locality a sufficient number of times to give results under typical conditions. Many data, some of which were useful to indicate size of fish, have had to be discarded because they are too summarized in form or because records have been kept only of successful outings or because

of some inadequacy of specification. The evidence left is somewhat fragmentary, and with one exception permits only of comparisons being made between results of a few excursions made long ago by one or more anglers with results obtained by a few other anglers more recently.

In some cases it is possible to compare the results obtained in an average hour of time spent fishing in the early days of angling with the yield per hour in recent years. More often it is necessary to base the comparison on results of a typical day: each visit to a stream, whether successful or not, and whether little or much time was spent, is considered a full day for this purpose.

Where the measure of abundance is the typical daily catch, it is essential to make allowance for alterations in the permitted maximum daily catch. Therefore, where, in any early period, a daily catch was recorded in excess of the daily number permitted at some later period, it was reduced to the daily limit ruling in the latest period for which data are available.

There does not appear to have been a daily bag limit in some early periods represented by data. In Southland, a limit of 30 fish a day was imposed in 1910. Generally, limits continued very high until about 1932. Thereafter they were reduced in most districts—in some cases to as little as 10 fish a day by 1945, and in one case as few as five.

EVIDENCE OF RELATIVE ABUNDANCE—SOUTH ISLAND

The Oreti River

Beginning with the season 1889–90 and finishing with the season 1929–30, the late Neil McKay recorded his captures of trout in the Oreti River and elsewhere in Southland in 35 of the 41 seasons. Mainly he fished with wet fly in the Dipton–Benmore reaches of the Oreti and made 1441 daily excursions in the 35 seasons. When allowance is made for change of the daily limit, there remain 19,430 brown trout, totalling 15,523 lb., which were taken with the same method in the same portion of the Oreti. This angler, who was recognized as outstandingly skilful with the wet fly, lived beside the river.

In presenting in Table V records of McKay's captures in successive periods, there is shown, in addition to the average daily number of fish for successive periods, the weight of the average daily bag. This is a better indication of the value of the fishery than size alone or numbers alone. The records relate to the captures of one angler over a period when the fishery was subjected to the influence of changing numbers of anglers. Therefore, as a rough guide to the extent of the total angling effect directed against the stock, approximate figures are given for the total amount of licence revenue per annum.

TABLE V

Period	Days Fished	Total Fish	Av. Wt. in lb.	Average Daily Catch No. of Fish	Average Daily Catch Weight in lb.	Av. Annual Licence Rev.
1889–1890 to 1898–1899	258	2810	0.93	10.9	10.1	£ 260
1899–1900 to 1908–1909	575	7802	0.88	13.6	12.0	£ 577
1909–1910 to 1918–1919	260	4202	0.75	16.2	12.2	£ 757
1919–1920 to 1929–1930	348	4616	0.63	13.3	8.4	£1242

McKay's figures are accepted as reliable. The mode of presentation of his records, however, makes no allowance for two possible variables. There is no evidence as to whether or not his skill changed or as to whether or not the average number of hours he fished each day changed from period to period. For purposes of discussion, the analysis is taken at its face value.

Average size of individual fish fell slightly from the first to the second period, and thereafter at a greater rate. The rate of fall from the second to the third period and from the third to the fourth period was approximately uniform. The abundance of fish, as indicated by the number which could be caught in a fixed time, was greater in any of the three later periods than in the first period. It increased from 1895 to 1915, and thereafter dropped, but only to about the quantity shown in 1905. The increase in numbers of trout was such that, despite their fall in size, a typical day's angling yielded progressively greater weights of fish until the 1920's, when the situation changed. Then the daily catch fell in weight, not because fish were less numerous than they had been twenty years earlier, but because their average weight was less.

So far we have considered what the stock yielded to one angler only. The licence revenue for the four periods provides a rough measure of total angling effort. If the total effort in the earliest period is given the value of 1, values for the four successive periods will be 1, 2.2 times, 2.9 times, and 4.8 times. Thus, in the last period there were about five anglers fishing where one had fished in the earliest period. By multiplying the daily catch by the total angling effort, values are obtained and shown in Table VI which give some indication of the relative abstractions by anglers in the four periods.

TABLE VI

Angling Season—Period	Daily Catch of One Angler		Index of Total Angling Effort	Indices of Total Abstractions	
	Nos.	Wt.		Nos.	Wt.
1889–1890 to 1898–1899	10.9	10.1	1.0	11	10
1899–1900 to 1908–1909	13.6	12.0	2.2	30	26
1909–1910 to 1918–1919	16.2	12.2	2.9	47	35
1919–1920 to 1929–1930	13.3	8.4	4.8	64	40

The excess of fish over the daily limit of 30 introduced in 1910–11 amounted to 8 per cent. before that time, and has been ignored here.

These indices are not, of course, accurate measures. They should, however, indicate approximately the relative results of angling from period to period. In round figures, the number of fish killed in the last three of the four periods were, respectively, three times, four times, and six times as great as in the first period.

It will be noticed that the relative increase in rate of abstraction of fish was greatest (a threefold increase) from the first to the second period, during which time the decline in average size of fish was less than half what it was from any subsequent period to the next succeeding period. The data, as they stand, afford no indication of a decline in the abundance of trout at any time in the known history of the fishery. There was clearly a change in relative quantities of large and small fish, but no progressive decrease in absolute numbers is shown. Had the numbers and weight of fish comprising the daily bag of the individual angler

fallen in inverse proportion to the increase of total angling effort, the changes would have indicated that the same quantity of fish was being taken but was being shared among an increasing number of anglers. The available evidence does not indicate this.

Only when reference is made to the total weight of trout abstracted is an indication found that a stage was approaching when additional anglers could be accommodated only by sharing what a smaller number of anglers had previously taken. From the first to the second period the number of anglers more than doubled, and there was at least a proportionate increase in the total weight of fish taken. From the second period to the third period, the increase in angling effort was only about one-third, and the total catch still increased proportionately. However, from the third period to the last, when angling intensity increased by five-eighths, the total weight of fish killed increased by one-seventh.

It seems legitimate to conclude from the foregoing that over a period of 41 years, during which the average size of fish taken by anglers fell progressively, the total abstraction of fish increased so greatly that, in the final eleven years, the annual abstraction was by number nearly $6\frac{1}{2}$ times and by weight 4 times what was taken per year in the first decade. If this is correct, the deterioration of average size alone of fish does not afford satisfactory evidence of depreciation of a fishery in terms of gross yield. Are these findings reconcilable?

We have considered only one influence of many which could have caused changes in the composition of this particular stock. When Percival (1932) made his survey of the Oreti, the scope of his inquiry was largely limited to the nature and causes of alleged changes in size of fish there. He concluded that causes other than changes in rate of growth were sufficient to explain the very evident fall in size. Particularly he ascribed the fall to the great increase in angling effort, which resulted in fish being captured before they grew so old as formerly. Conclusive evidence that growth had not changed, such as might have been obtained if collections of scales taken in earlier times had been available, was lacking. The popular claim that growth had diminished was coupled with the assertion that food organisms had been very much depleted or had become extinct. Percival showed, by examination of many waters, that the quality and extent of the food resources was greatly conditioned by the physical environment, and that in the Oreti and other waters supporting large stocks of trout the invertebrate fauna was in quantity and quality what the physical environment led one to expect to find there. Such a finding does not establish that trout would not grow faster if more food were available.

Again, evidence of a well-maintained fauna with a moderate or good rate of growth of trout in recent times is not evidence of absence of competition by trout for food. On available evidence, the possibility must be admitted that, even if food resources in the Oreti have in no important way been depleted, increase in the numbers of the consuming stock may have resulted in individual trout in recent times having less food available to them than in former times. If this had occurred it could afford a partial or complete explanation of how size could have dropped, despite an apparent maintenance or even increase of numbers of trout. There are

other equally possible explanations, all unfortunately equally difficult to investigate because of lack of clear evidence as to past conditions.

Change could have taken place in the extent and character of the available spawning areas. Elsewhere (Hobbs, 1940) I have shown that a substantial proportion of the spawning redds in the Oreti were in recent times overlapped with the probability of resulting loss of part of the contents. Again, it is evident that only a small proportion of the great quantities of trout fry produced in the Oreti survive to be taken as well-grown fish by anglers.

Much of the loss may be ascribed to predation. There is no evidence as to the relative numbers of predators in the river in early and in recent times. Change of conditions, by permitting increased successful spawning, or by enhancing chances of survival of young fish, could permit more young fish to become available to the angler and tend to offset any increased destruction of larger fish. It will be apparent that in these circumstances a decrease in the average size of fish taken by anglers could occur, although the total numbers of fish of all sizes might be maintained.

Angling may afford little indication of the nature of a stock of trout. The stock produced in the Water of Leith consists in part of fish which, while small, remain in fresh water and available to the angler and, in part, of large mature fish which enter from the sea, mostly when the angling season is over.

The position may be contrasted with that of Lake Marymere in North Canterbury, which has no tributary streams. This lake contains a self-supporting stock of brown trout. The inshore waters within reach of the angler are dominated by large mature trout, mostly of about 3 lb. in weight. In the course of much angling there, I have not caught a brown trout of under 1 lb. in weight nor heard of anyone catching one of such size. Yet the lake must, at any time, contain many trout of smaller sizes.

In the case of the Oreti, we have seen that the use of artificial minnow, possibly because it gave better penetration of deep water and appealed to fish with larger mouths, took fish of a greater average size than were taken with artificial fly, which takes fish mainly of above legal size and appeals less to more numerous smaller-size groups. It does not necessarily take a fair sample, even of the portion of the population that may lawfully be taken. Further, it is employed against only that part of the population which occupies the area during the angling season. Fly-fishing by so skilled an angler as McKay was, in a part of the river with which he was extremely familiar, would tend to be directed against fish occupying positions which experience had shown usually yielded the best fish.

It will be seen that the samples of fish which demonstrate the fall in size of fish in the Oreti are, by the sampling method employed, selected from among the intermediate sizes of fish comprising larger-size groups. The fact that after 1930 spawning areas were still being used to somewhere near capacity shows that, whatever reduction there may have been in the numbers of larger fish, it is unlikely to have reduced substantially the quantities of young being produced. Elsewhere (Hobbs, 1940) grounds have been given for the belief that a stock in the early stages of exploitation may include an excess of mature fish which could be removed

without a corresponding decrease of the amount of successful reproduction in a stream.

Available evidence is not conclusive on all points, but it suggests (1) that, because of a great increase in angling intensity, directed principally against fish in the larger-size groups, the average size of the fish caught fell; (2) that associated causes of this fall in size could conceivably have been relatively less food available for individual fish, or a greater survival of young fish to legal size; (3) that, because of the selective effect of angling, the fall in average size of fish caught is not indicative of reduction of the stock as a whole; (4) that between 1895 and 1915 the numbers of trout of legal size continued to increase, and in 1925 there were still more than in 1895 and as many as in 1905; (5) that over a period of years, during which size fell progressively, there was an increase in total angling catch estimated at more than sixfold in numbers and fourfold in aggregate weight; (6) that this greatly increased destruction took place without any substantial lowering of the effective reproductive capacity of the stock; (7) that this was possible because births and deaths were not balanced in the Oreti, and the births permitted replacement, plus production of an excess of fish for which facilities for reproduction at optimum efficiency were lacking; (8) that such accumulated excesses have helped the stock to withstand the increased extent of angling; (9) that after 1920 the increase in numbers of anglers began to affect the weight of the average catch of fish taken by other anglers, and partial sharing of the portion of the stock available for exploitation began.

OTHER SOUTH ISLAND RIVERS

A few records from four other South Island streams permit the making of comparisons of angling conditions in recent years with conditions as they were soon after angling began in 1874. The Otapiri forms part of the highly productive Makarewa sub-system of the Oreti River. The Pomahaka sub-system of the Clutha River, of which the Waipahi is part, is also very productive water. The Waiwera is a smaller tributary of the Clutha. The annual yield of the Pomahaka itself is estimated, from diary records, to be possibly as much as one-third of the total trout taken in the Otago Acclimatization District. The annual catch in the Waipahi and the Waiwera is estimated to be, in each case, about one-sixth that of the Pomahaka.

In both periods fish from the Otapiri were taken with artificial fly. In the other three streams, the more recent of each set of samples were taken with artificial fly. The lure used earlier is not known.

Data relating to these waters are shown in Table VII. As an indication of change in total fishing intensity, approximate figures are included for average annual licence revenue. Where changes of licence fee between the periods makes it necessary, the amount of the increase has been deducted.

TABLE VII

Stream	Period	Av. Annual Revenue £	Anglers Recording	Days Fished	Catch per Angler per Day: No. of Fish	Catch per Angler per Day: Aggregate Wt. lb.
Otapiri	1890–1902	260	1	18	12.9	13.2
	1930–1932	1601	4	18	11.7	12.5
Pomahaka	1882–1883	320	1	26	5.2	9.1
	1935–1945	1950	3	87	3.7	5.1
Waipahi	1882–1883	320	1	46	1.7	4.6
	1935–1945	1950	3	50	2.9	3.6
Waiwera	1879–1882	280	3	13	2.1	4.1
	1935–1945	1950	4	24	2.2	2.7

It will be observed that these data are less satisfactory than those from Oreti. The number of anglers at different periods is small, and differences in their skill could affect the results. In three cases different lures may have been used. Further, the number of angling excursions is not very great, and results could be influenced by less favourable weather conditions at one period than at another. The following comments are made subject to these reservations.

The early captures in the Otapiri were made by the late Neil McKay. The later captures were made with the same angling method by four skilled anglers. The data show as great a uniformity in number of fish and aggregate weight per day as could be expected, even if different anglers had fished in the same season, instead of after an interval of 30 years. The data suggest that the standard of angling offered by this stream had not changed in numbers or size of fish. This is so, although in the latter of the two periods angling intensity in the Southland District was six times as great as formerly.

An interval of fifty or more years separates the periods in which samples were obtained from the three portions of the Clutha River system. In the Pomahaka, where the potential total angling effort is now six times as great as formerly, the daily catch per angler is, by number, about two-thirds what it used to be and, in weight, still more than half what it was fifty years back. If the angling effort directed against this stock has increased proportionately to increased sales of licences, 30 lb. weight of fish is being taken where 9 lb. used to be taken, although to-day the larger catch is made up of fish of a smaller average size.

The Waipahi shows a substantial increase in the number of fish now taken by one angler each day, despite a sixfold increase in angling in the district. The weight of the individual daily catch is a little less, because average size has dropped, but the total yield is now possibly as much as five times what it formerly was.

The number of fish taken per day by an angler in the Waiwera is substantially unchanged, but the weight of the daily bag has dropped by one-third because the size of individual fish is now less by that amount. In the greater interval separating the periods of sampling the Waiwera, the total angling effort has increased seven times.

Data from these four waters present interesting features: the Otapiri, maintenance of numbers and weight of fish in the daily catch of the individual angler;

the Waipahi, increase in numbers but reduction of weight; the Waiwera, maintenance of numbers but reduction of weight; the Pomahaka, reduction of both numbers and weight. Present evidence is inadequate to warrant discussion of possible reasons for these contrasts. The known variable which influences these stocks is intensity of angling. Other unknown influencing factors may also have changed.

It would be unsafe to consider the stock of any of these four waters as something restricted in range to the particular stream named. In all cases, and to differing extents, there may be interchange of stock between these tributaries and the rivers they enter and, possibly, partial replacement of fish abstracted. The changes indicated in the fishing afforded by the three Clutha waters are interesting chiefly in that so small an effect is shown on the average catch between times when angling intensity has increased so greatly. The data suggest that in the earlier of the two periods only a small portion of what was available for exploitation was indeed exploited. No lessening in the numerical abundance of fish is indicated, although large fish are less in evidence. Even in the Pomahaka, where the individual angler now takes fewer per day than formerly, it does not appear that the total production of fish is any less.

CHANGE IN ABUNDANCE—NORTH ISLAND

Data suitable for comparison are available from the Manawatu and its tributary, the Makakahi. Those from the Manawatu are more satisfactory, for they are less likely to be affected by differences in skill of individual anglers. In each case a typical hour of angling is taken as the basis of comparison. Amplifying data on the basis of results per day are given for the Makakahi. The comparisons are of results with the same lure or reasonably similar proportionate assortments of lures. Relevant figures are given in Table VIII.

TABLE VIII

Stream	Period	Av. Annual Revenue £	Anglers Recording	Hours Fished	Catch per Angler per Hour: No. of Fish	Catch per Angler per Hour: Aggregate Wt. lb.
Manawatu	1890–1900	310	6	100	1.03	1.83
	1940–1942	1500	10	131	0.86	1.79
Makakahi	1895–1905	575	2	16.5	1.27	1.18
	1940–1942	1500	6	234	1.22	2.99
				Days Fished	Catch per day	
Makakahi	1895–1905	575	3	37	3.35	4.27
	1940–1942	1500	6	60	4.76	11.66

In the Manawatu, after an interval of 40 years, during which the angling effort became about five times as great as formerly, it was still possible for an angler to land, per hour, much the same weight of trout as formerly, although, in the latter period, the catch comprises slightly fewer fish of a slightly greater average weight. The two sets of data from the Makakahi show that after 35 years, during which the total angling effort nearly trebled, the individual angler was able to take more than double the weight of trout; the improvement in this case represented increase in size of fish.

Features in the Manawatu fishery are the absence of any tradition of very large fish in former times, the paucity of both under-sized fish and trout of over 5 lb. in anglers' catches, the relative neglect by anglers of very extensive lower reaches of more quietly flowing water, and the absence of evidence of any considerable influx of trout from the sea. These two last-mentioned features are shared by the Wanganui and Waikato, which enter on the same coast farther north.

The river-mouth fisheries and evidence of trout entering from the sea in New Zealand are found almost exclusively in rivers where unstable beds of coarse gravels extend down into very short tidal reaches.

GENERAL DISCUSSION

In this section discussion sometimes tends to be carried further, possibly, than the weight of data warrants. Small samples are sometimes relied on, although they may have little statistical significance. In part, small samples have been included for purposes of record. In part also, they illustrate the paucity of records of an essential kind and what could be learnt from such data if they were available in greater quantity. Very few of the data used are taken from official records of acclimatization societies. The bulk are taken from diaries of individual anglers. It is to a few individuals that we are indebted for so much as we can now piece together of the angling history of streams. The best records are those from the Oreti, contributed almost wholly by one angler.

For many years field employees of acclimatization societies have patrolled streams to prevent poaching and to ensure that anglers have licences. Although they have to interview anglers for this purpose, they have not been required to note the number of anglers encountered and the methods they employ and the results they obtain. It is essential to the good management of fisheries that attempts should be made to learn the nature and extent of the yield of different waters. This calls for either carefully organized voluntary diary-keeping by anglers or organized census-taking by field staff and co-operatives or a combination of both methods. In some districts, it might be found most practicable to study the weight and dispersal of the total angling effort and to check the results, not in all streams, but in a carefully selected sample series.

SUMMARY

Such little evidence as to past and present status of stocks as is available may may be summarized thus:—

There is evidence that in a few waters trout taken by anglers were usually of a larger size, at a time when possibly they were fewer in number, shortly after their establishment. No significant change in size of fish at any time in their known history is shown in certain streams. Where, in other waters, a progressive deterioration of size is shown, it ended in most cases by about 1900, and in only one stream is it shown to have continued into times when present-day anglers could have noticed it.

There is no satisfactory evidence that the yield of waters generally, in terms of total weight of fish, has been less in recent years than it was last century. In particular cases, where evidence is available, it suggests that there has been a great increase in total yield to anglers.

While the number of anglers has increased greatly, individual anglers to-day, on some waters, still take much the same weight of fish per unit angling effort as others did last century. In other waters, the catch of the individual angler is now less; but nowhere is there evidence that it has dropped in inverse proportion to the increase of total angling effort. Thus present evidence does not show that abstractions have yet generally reached the maximum that should be possible without threatening the continued well-being of stocks.

As the evidence comes from a limited number of waters, and a number of these may be above usual quality, the statement is not necessarily applicable to all New Zealand rivers.

III.—Development and Distribution of Angling

DEVELOPMENT

In an earlier section, district angling licence revenue was used as an index of local angling intensity at different periods. Here it is proposed to consider the growth of angling as a pastime in the country as a whole. Licence revenue is used as a measure of potential angling effort. The application of that effort is governed by distribution of the population in relation to angling waters, ease of access and transportation, the amount of available leisure, and other factors.

Until the season 1936–7, the general licences for men cost 20s. for a full season, or 12s. 6d. for a half-season, and smaller quantities of women's and boys' licences were sold for lower fees. Returns from different districts show that in 1936 £100 of licence revenue was usually contributed by 125 anglers in the different categories. In 1936–7, the general licence fee for adult males was increased by 25 per cent.; 10 per cent. of the total licence revenue was allocated to research and the balance remained available to the local administrative authorities. Subsequently the fees in the general licence districts of the North Island were raised from 25s. to 30s. The mean annual licence revenue from general and special licensing districts for the years ended March, 1935, 1936, and 1937 was £13,432. Of this, £4,292 was revenue from the special licensing districts of Rotorua and Taupo. The balance of £9,130 was from sales of general licences.

The total number of holders of general licences, on the basis of 125 to each £100 of revenue, was about 11,400. The purchasers of special licences comprised a proportion of local residents, but in addition included very many visitors, some of whom may also have held general licences.

Lack of certain records, changes of boundaries, and some local changes in the system of licensing make impracticable the presentation of a comprehensive account of the growth in the demand for angling as evidenced by sales of licences. The study which follows is based on reasonably complete records from the four major South Island societies and two major North Island societies, which in 1936 together sold 84 per cent. of the total general licences.

In Table IX, where licence revenue is used as an index of the number of anglers fishing at different periods, it has been necessary to make a proportionate deduction from the gross revenue (shown in parentheses) for the amounts by which charges for licences were increased in recent periods. Thus modified, the mean

annual revenue is shown for the first five years of successive decades from 1880. The mean annual revenue is also given for the pre-war seasons of 1936–7, 1937–8, and 1938–9, and revenue for the post-war season of 1946–7 is included.

Data on population for the first five and for the seventh period are from census returns for the first year of each period, as given in the New Zealand Official Year Books. For 1931–5, the mean of census returns for 1926 and 1936 is used. Data for 1946–7 are approximations reached by the author on the basis of the 1945 census return with allowance for subsequent repatriation of servicemen.

To avoid effects of changes in age composition, data relating to the main licence purchasing portion of the population—males of 15 years and over—are used.

Indices of significant changes in distribution of population are also given in Table IX.

TABLE IX

Period	Distribution of population Percentage Urban	Percentage in N. Island	Mean annual licence rev. £	European males 15 years and over	Revenue per 1000 of population £
1881–85	39.8	39.4	340	169,600	2.0
1891–95	43.1	44.9	1350	207,400	6.5
1901–05	45.3	50.5	3300	275,300	11.9
1911–15	50.1	55.9	4300	369,100	11.6
1921–25	55.9	60.8	6100	425,300	14.2
1931–35	58.8	62.4	7700	520,900	14.8
1937–39	59.3	62.9	7500 (9600)	554,400	13.5
1946–47	63.1	67.3	7650 (9950)	610,000	12.5

In the earliest period, revenue came almost wholly from the Otago Province. Ten years later, angling was available in most South Island districts, but only in limited areas of the North Island. At the turn of the century it became very generally available. Sales per population 1000 had increased to a figure which showed little change until after the Great War.

In the depression years of the early 1930's, sales per thousand held at a point higher than ten years earlier—possibly a reflection of the value of the anglers' catch to needy households at a time of economic stress and enforced leisure.

Between the depression and World War II, when sales might have been expected to increase, they dropped slightly. It would appear that temporarily the long-term tendencies for sales of licences to increase, both in absolute numbers and relatively to population, were arrested by the imposition of higher licence fees.

Although in Table IX a reduction in sales in relation to population and a tendency for total sales to stand still are shown, the true position was otherwise. The figures for the 1946–7 season are depressed because, while sales advanced in the four South Island districts, they remained steady in one of two North Island districts and fell very considerably in the other. Reference to data from a more comprehensive series of districts, for which early records are not available for inclusion in Table IX, show a general increase in licence sales between 1936–7 and 1946–7. Sales of licences in the country as a whole increased by 22 per cent., while the licence-purchasing group of the population is estimated to have increased by only about 15 per cent. in the same period.

In the North Island in the last ten years, sales have increased by 40 to 50 per

cent. in the smaller east and west coast districts. Exploitation, largely by visiting anglers, of the major central North Island lake fisheries of Taupo and Rotorua increased by 50 per cent. in Taupo and 15 per cent. in Rotorua.

The major cities of the North Island lie towards the southern and northern extremities respectively of the Wellington and Auckland districts, in each case fairly remote from the best fishing streams. The recent substantial increase in sales in more central areas of the North Island may in part reflect diversion of angling effort from the districts in which the major cities lie.

The general tendency for sales of licences to increase disproportionately to the increase of population is interesting in several respects. It continued long after trout became well established in the waters which carry most of the angling. Improved access to remoter waters and improved means of transport tended later to spread the increased angling effort over a wider field. In comparatively recent times, there has been much heavier exploitation of stocks in many of the series of lakes in the eastern foothills of the Southern Alps and in the better known lakes of the central North Island. In both islands most of the important lake fisheries lie in sparsely populated country.

The very substantial proportionate reduction of rural to urban population tends to offset the general effect of improved means of transport. In earlier periods a typical 1000 people included a far bigger proportion spread through rural districts handy to streams. Further, a bigger proportion of that 1000 lived in parts of the South Island where, as will be shown later, good angling waters are more abundant than in much of the North Island.

Increased leisure makes for more opportunity for angling. Where reduction of working hours lessens the working week to five days, more city dwellers are able to travel to remoter waters. The Official Year Book shows that combined groups of workers (other than agricultural and pastoral workers) were, in 1937, working only 890 hours for every 1041 hours worked in 1914. Mainly since 1936, a forty-hour week has come into operation in the great majority of industries, and increasing numbers of groups of workers have changed over to a five-day working week. The number of hours in the basic working week is not, however, a wholly satisfactory index, for during the recent war more overtime was worked and many retired people returned to work.

In general, the evidence is of a continuing increase in the demand for angling in most parts of the country. There is evidence that, to an undetermined extent, remoter waters are satisfying some of the increased demand. So far data available afford no indication that, generally, increase in numbers of anglers has compelled such a sharing of the total catch as to reduce the incentive of the individual angler. It would appear that the numbers of anglers may for a time be expected to continue to increase.

DISTRIBUTION OF ANGLING EFFORT

The distribution of licences in relation to population in different parts of New Zealand is shown in Table X in Fig. 1. The revenue given in the table is the mean for the financial years ended 31st March, 1935, 1936, and 1937, after abatement in the case of the last year by the amount of the increase in the rate of charges.

TABLE X

Area No.	Acclimatization Districts	Population (1000's) males 15 years and over	Annual revenue £	Revenue per 1000 of population £
1.	Manganui-Whangaroa, Bay of Islands, Hobson, Whangarei	25	6	0.2
2.	Auckland, Tauranga	154	850	5.5
3.	Rotorua, Taupo (special licensing areas)	—	4292	—
4.	East Coast, Waiapu, Hawke's Bay	39	286	7.3
5.	Taranaki, Stratford, Hawera, Wanganui, Waimarino	43	573	13.3
6.	Wellington, Feilding	101	1341	13.3
7.	Nelson, Marlborough	20	196	9.8
8.	Buller, Grey, Westland	16	181	11.3
9.	North Canterbury, Ashburton	69	1520	22.0
10.	South Canterbury, Waimate	17	939	55.2
11.	Waitaki, Otago, Lakes	59	1934	32.8
12.	Southland	24	1304	54.3

Data from the special licensing areas of Rotorua and Taupo are not comparable because there much of the revenue comes from non-residents. Collectively, the rest of the North Island areas contributed £8.4 of licence revenue per 1000 of the population as against £29.6 for all South Island districts.

A very striking increase in licence sales from north to south is evident. Sales are outstandingly high in the south-eastern and southern provinces of the South Island.

These data afford some indication, rather than a reliable measure, of the angling worth of different districts. For instance, in Area 2—the main centre of population, Auckland city—is more remote from good angling water than major centres are in other areas.

Although much effort is devoted by acclimatization societies to the maintenance of the stocks, little thought has been given to learning what the typical angler expects or gets for his efforts. Only in Otago has a well-organized effort been made to learn something of the yield of waters. A few anglers from other districts have co-operated in the furnishing of data used in Table XI.

The data relate to catches in angling seasons since 1932, and rarely later than 1942. In districts other than Otago, it has been necessary to avoid giving undue weight to the returns of any particular individual where some anglers made returns for a number of seasons and some for only one season. The typical catch for any district has therefore been computed for the means of seasonal catches of different individuals.

TABLE XI

Acclimatization District.	Seasonal Returns from Anglers.	Number of Anglers reporting.	Variation in Seasonal Catch.	Average No. of Fish taken.	Weight in lb. of Average Catch.	Average Weight in lb.	£ Revenue per 1000 of Population.
Auckland	49	31	1–131	34	60	1.77	5.5
Taupo (1)	32	15	15–300	146	676	4.63	—
Wellington (2)	63	31	4–206	57	105	1.84	—
Nelson – Marlborough	26	24	0– 87	36	115	3.20	9.8
South Canterbury	22	11	0–508	200	136	0.68	55.2
Waitaki (3)	34	14	7–282	55	52	0.96	—
Otago	468	—	0–607	87	91	1.05	32.8
Southland	23	10	62–408	200	304	1.52	54.3
Sundry Districts	36	15	24–262	88	166	1.89	—

Average of different districts: 100 fish, 189 lb.

(1) Diaries from three short-term licensees and twelve full-season licensees.
(2) Diaries almost wholly from residents of Manawatu catchment area.
(3) Diaries record catches in Kakanui River and not necessarily all captures in district.

The "Sundry Districts" category in Table XI comprises small numbers of returns from scattered districts and records from anglers who fished in several different districts. Because Taupo is fished principally by visitors and because data from the Wellington and the Waikato districts are not necessarily typical,

no attempt is made to relate quality of angling with the proportionate demand of the residents for it. The wide disparity in numbers of fish comprising seasonal catches and the small number of returns from most districts make it unsafe to draw definite conclusions from data presented in the table. In general, however, a substantial agreement is suggested between the quality of angling offering and the public's reaction as indicated by sales of licences.

(Above) Opihi River—near Fairlie, South Canterbury (Sth. Is.). This river and its Tengawai and Opuha branches and lesser tributaries provide some of the finest fly fishing in the country for brown trout and some quinnat salmon fishing in the lower reaches of the combined streams. (Plate V.)

(Above) Drought conditions at Quades Crossing on the Hae Hae Te Moana River—an important spawning subsystem of the Opihi. This is one of many South Island east coast streams where droughts frequently cause substantial loss of fish. In several districts efforts have been concentrated on artificial propagation of trout and little has been done to salvage fish in drought areas. (Plate VI.)

(Right) Spring creeks like this well-populated Opihi system tributary near Geraldine afford trout protection from floods and droughts. However, the stable conditions and abundant cover favour heavier stocks of eels than are found in the Hae Hae Te Moana and other streams with more open shingle beds. (Plate VII.)

Manawatu River — This river and its tributaries, draining portions of the Hawke's Bay and Wellington Provinces, comprise the most important brown trout river system of the North Island. Comparison of anglers' captures in the eighteen nineties and early nineteen forties shows that, despite a five-fold increase in total angling, the catch per hour of the individual angler is substantially unchanged. (Plate VIII.)

Horokiwi River—a smaller and unimportant Wellington district angling stream; yet one so typical of many small streams as to be a very useful sample area for biological observations. Studies here have resulted in valuable advances in knowledge of survival of trout from the fry stage onwards, of the relation of angling catch to production of fry and of relationship of a trout population to its food supply. (Plate IX.)

Wainui-o-mata River — Despite its proximity to Wellington City (Nth. Is.), and despite the diversion of much water for city purposes, this small stream is shown by diary records to have continued to produce trout of a very uniform size for over 50 years. (Plate X.)

PART II

Recent Management of Fisheries in New Zealand

ANALYSIS OF EXPENDITURE OF INCOME FROM FISHERIES

ACCLIMATIZATION SOCIETIES do not usually keep separate accounts of their income and expenditure for fisheries and game. Charges for secretarial and administrative services and for law enforcement are not apportioned. Staff responsible for law enforcement is often responsible for distribution of hatchery products. Allowance is only sometimes made for depreciation of plant. Therefore, estimates of expenditure of fisheries revenue, based on annual reports of acclimatization societies, are necessarily approximations.

Reports from the Auckland, Wellington, Nelson, and Southland Societies for the years ended March, 1936, and 1937, are representative of conditions usual in pre-war years in most parts of New Zealand. Their mean annual combined income was:—

	£
Fish Licence Revenue	3,792
Game Licence Revenue	4,341
Opossum Royalties, Fines, and Interest on Funds	798
Total Income	£8,931

Secretarial and general organizational charges amounted to £1,380. This sum, when shared proportionally amongst the sources of income, reduces the fisheries income by £584 to £3,208. The latter sum was the amount available for fisheries maintenance work. This net sum of £3,208 was disbursed thus:—

Net Hatchery expenditure	£2,221, or 69 per cent.
Fisheries research	231, or 7 per cent.
Predator destruction	66, or 2 per cent.
Balance available for ranging	690, or 22 per cent., of which some portion is properly chargeable to hatchery work for distribution of hatchery products.

Annual reports of different organizations showed a variation of from 52 per cent. to 82 per cent. of gross fisheries revenue spent on hatchery work. Results, in hatchery products for local release, per £1 of hatchery expenditure, differed greatly, not only in the kind of product, but in the amount produced. In four different districts the approximate results per £1 expended were:—

(1) 1,100 eyed ova and 1,400 fry.
(2) 4,500 fry.
(3) 1,900 fry and 20 fingerlings.
(4) 1,400 fry and 350 fingerlings.

The first two cases are those of societies which trapped wild fish to obtain ova. The first of these two sold quantities of eyed ova, the value of which has been offset against hatchery costs for purposes of this analysis. The last two cases are those of societies which kept full-time hatchery staffs, but which purchased eyed ova and retained very different proportions of the resultant fry for further development. These different cases suggest considerable differences in efficiency and value received for expenditure.*

Destruction of predators may have absorbed more funds than available figures suggest, as this work was attended to, in part, by the ranging staff.

Fisheries protection work, to which possibly as much as 22 per cent. of available funds was applied, was a service which varied greatly from district to district. Some districts employed full-time fish and game rangers. Others, at the time of the year when spawning fish were highly vulnerable to poaching, used their field staff for trapping fish or for hatchery duties.

As approximately 70 per cent. of available funds have been directed to hatching and rearing trout, the study of stock maintenance practices which follows must, primarily, be a study of hatchery operations.

GROUNDS FOR OPERATION OF HATCHERIES

It might be expected that practices to which most societies have for so long devoted a major portion of their fisheries income would have been the subject of frequent examination with a view to learning to what extent such operations were necessary. Except in very recent years, reports offer no evidence of a will to do more than to follow unquestioningly practices which with time have become traditional. There has been consideration of the question at which stage of development the product of the hatcheries should be released and also of whether the quantities released might not be taxing the feeding capacity of streams.

There speculation has largely ended, and inquiry has not been stimulated even by knowledge that previously populations of trout flourished without hatchery aid for many thousands of years; nor would any marked impression appear to have been created by the fact that populations of duck, deer, and opossums—all

*The duties of hatchery staffs, in districts more generally, have varied much. In some, the same officers have trapped wild fish, collected ova, tended the eggs through the vulnerable pre-eyed stage, dispatched eyed ova to other areas, retained and hatched quantities comparable with those handled in other districts, taken a major part in distributing the hatchery output, and found time to do a reasonable amount of ranging, salvaging of fish, and destruction of predators. In other districts eyed ova have been received and hatched. Some staffs have retained and fed a substantial proportion of the resultant fry and taken an active part in law enforcement and general duties. Other staffs have retained only a small quantity of fry for rearing to provide a nominal and almost exclusive duty for about eight months of the year. Lack of knowledge of the amount of work involved and exaggerated ideas of the amount of ability required to hatch eyed eggs have led in a few cases to extremely uneconomic employment of staff.

important sources of income in the past—have managed to withstand heavy exploitation, despite lack of artificial protection for their young.

The Southland Acclimatization Society (in a letter dated 12th June, 1934) states: "The principle of artificial hatching seems to have been handed down from the early days of acclimatization in Southland when certain streams contained no trout at all. . . . It is the general opinion that artificial hatching is justified by results, and this is accepted almost as an axiom by anglers and members of acclimatization councils and by the staffs of societies." Personal experience as a member of the council of a major acclimatization society, contacts with councils of many such bodies, and study of their annual reports all suggest strongly that the Southland view cited fairly represents general New Zealand opinion of a few years back.

A very common tendency is shown, in past reports, to attribute improvements in fishing to increased releases of young, if such have been made, and to ignore or attribute failure to other causes in equally numerous instances where fishing has not improved following larger releases.

Conclusive proof of benefits resulting from maintenance operations is not offered, not necessarily because in no cases could it be obtained, but rather because the assumption that such work is beneficial has been so widespread that it has not been thought necessary to seek conclusive evidence. In this respect, the views of fisheries administrative bodies here in New Zealand have not differed greatly from those of similar bodies elsewhere.

THEORETICAL BASIS OF HATCHERY POLICY

While artificial propagation enables young fish to be assembled for transfer, the primary aim of those who have employed it in New Zealand has been to improve on natural processes rather than simply to facilitate transfer of stock. The belief in its advantages has been such that it has been thought desirable to collect the eggs from a portion of the fish in a few streams, to return a fractional part of the resultant young to such waters, and to distribute the rest over many rivers and lakes.

It has been understood fairly widely that, while wild populations of insects, fish, birds, and mammals from time to time fluctuate not a little, in general they tend over a period to maintain an equilibrium which requires a balance between births and deaths. Further, it has been a matter of common knowledge that different forms of animal life produce greatly contrasting numbers of eggs or living young and that the frequency of reproduction and quantity of eggs or young must normally be sufficient in the case of each species to ensure its existence. Thus the quantity of eggs or young produced by the average reproductive component of a population will vary from species to species according to the hazards which will be encountered in life by different species.

Eels, hake, and cod produce great quantities of small eggs which drift free in the ocean. The efficient nest-builders, the salmon and trout, produce relatively fewer and larger eggs. Sharks, dogfish, and skate produce still fewer large and well-developed young or a few very big eggs with heavy protective cases. No

matter what the species is, in each case the quantity of eggs or young is, broadly speaking, that needed to maintain it. Put another way, the producers of a quantity of eggs or young may be themselves considered as having developed from a production of eggs or young similar in number to their own production. It is this knowledge—that of the many eggs produced by a pair of trout, extremely few will in nature develop into mature fish—that has led man to endeavour to improve on Nature by affording protection to the eggs and young stages.

Where this practice of artificial propagation of trout develops to the extent it has in New Zealand, then necessarily its development must be attributed to a belief in three underlying assumptions:—

(1) That artificial propagation is an improvement on natural processes.

(2) That it is practicable to apply it to a sufficient proportion of the total eggs produced to make a significant difference to stocks.

(3) That funds used in this manner give a better return than if spent in other ways to achieve the same ultimate object—better fishing.

It is true that, in a sense, hatchery work is carried out for the secondary purpose of assembling stock at stages suitable for transference to other waters. As has been stated, the employment of hatcheries was incidental to the establishment of certain species in New Zealand when conditions of transport were different from those of to-day. The acclimatization phase of hatchery operations is no longer important, but survives, in limited form, where attempts are made to extend the range of long-established species.

The regular collection of eggs from a few waters in New Zealand for distribution of their products into many streams already containing trout comprises so large a part of New Zealand hatchery operations that it requires some consideration. At first sight it might appear that the purpose of such endeavours is to transfer stock from unfished waters, or from waters where the stock exceeds angling requirements, to more heavily fished waters. In recent years Southland, Otago, North Canterbury, and the Lake Taupo areas have been the main source of supply of New Zealand hatcheries. In Southland, earlier, collections of eggs were made in heavily fished portions of the Mataura system and, later, were continued in upper portions of the Waiau system, despite its development, with improved access, as an angling area. In Otago a major and regular source of supply has been the Leith, which flows through the principal city. North Canterbury has drawn supplies almost exclusively from the Selwyn River, where probably the greatest concentration of anglers' huts in New Zealand is to be found. Of the Taupo area, it need only be said that its fame as an angling resort extends far beyond New Zealand.

It is not the case generally that hatcheries are employed to provide stock for transference from lightly-fished to heavily-fished waters. Rather is it the case that trapping in a very few streams will provide the number of eggs it proves practicable to handle in all New Zealand hatcheries. Streams are selected for trapping mainly because the difficulties of trapping them and of obtaining sufficient eggs are less than in the average stream. Because, after treatment in hatcheries, the product of some of the fish of only a few of the many streams containing them is thought to be worth distributing over many, it is clear that a belief in an improvement on natural processes is implied. To such an extent, if at all, as the

aim is solely one of transfer, it must be believed that it is more practical and economical to do this by collecting and hatching eggs than simply by netting wild fry or larger fish.

Finally, reports show that purchases or interchanges of ova are sometimes made to avoid supposed dangers of inbreeding. This would seem to imply a belief that the introduction from time to time of "fresh blood" is beneficial to a stock, and that the quantities handled are sufficient to obviate this supposed danger. As an instance of this type of operation, between 1920 and 1930 several consignments of from 100,000 to 250,000 ova were sent from the South Island to Rotorua and Taupo Lakes, which are known to have annual productions of eggs ranging into many millions. Quite apart from the question of whether or not "fresh blood" may be beneficial, it is clear that such small quantities of eggs as were transferred could not have been expected to have an appreciable result unless it were believed that this small hatchery product was significant alongside the many millions of eggs produced there naturally.

It will be seen that whether hatcheries are operated in the hope of reducing losses presumed to occur in Nature, or to assemble stock of a convenient size for transfer, or to attempt to improve stock by the infusion of "new blood," **two main questions require consideration:**

(a) **To what extent, if at all, is artificial propagation an improvement on natural reproduction?**

(b) **Is the quantity of eggs handled sufficiently large to make any significant general difference?**

Before attempting to answer these questions, further consideration must be given to the nature of hatchery operations in recent years.

SCOPE AND NATURE OF HATCHERY OPERATIONS

In the years ended March, 1935, 1936, and 1937, hatcheries were used in 18 of the 30 districts into which the country was then divided for purposes of fish and game administration. Three districts avoided the local use of hatcheries by purchasing fry hatched elsewhere. Three more had the partial use of hatcheries in adjoining territories. In six districts no hatchery-produced stock were handled, in one case because, in preference, funds were devoted to salvage work in drought areas and, in four cases, because the districts were primarily game areas in which little or no angling revenue was produced.

Eggs were collected in ten districts—Southland, Lakes, Otago, Waimate, South Canterbury, Ashburton, North Canterbury, Nelson, and Westland—all in the South Island—and Taupo in the North Island. Eggs of quinnat salmon only were collected in Waimate, rainbow trout only at Taupo, of Atlantic salmon, rainbow and brown trout in Southland, of both species of trout in Otago, South Canterbury, Ashburton, and North Canterbury. In the Lakes, Nelson, and Westland districts. only ova of brown trout were taken. In Ashburton, Nelson, and Westland, trapping was carried out solely to help meet local requirements. From other districts sales were made which resulted, on balance, in local releases of substantially fewer fish than the numbers of eggs collected.

In the three years mentioned, the approximate average annual quantity of eggs handled at all stations was 20,000,000.*

The average annual collection of eggs was as follows:—

Ova of brown trout	11,558,000
Ova of rainbow trout	7,713,000
Ova of quinnat salmon	527,000
Ova of Atlantic salmon	246,000
Total Ova	20,044,000

Of this quantity all the eggs of quinnat and Atlantic salmon and of brown trout, as well as 10 per cent. of the eggs of rainbow trout, were collected in South Island waters. With the exception of 2.5 per cent. of the brown-trout ova, which were from pond stock, all were obtained by trapping runs of wild fish.

The average annual collection of 773,000 salmon eggs was disposed of thus:—

Exported from New Zealand as eyed ova	21,000	or 3 per cent. (approx.)
Released (almost all as fry) in streams where collected	596,000	or 77 per cent. (approx.)
Released as fry elsewhere in N.Z.	155,000	or 20 per cent. (approx.)

Losses are not recorded.

In the average year the total of 19,271,000 eggs of both species of trout was disposed of in the following manner:—

Eyed ova exported from N.Z.	245,000	or 1 per cent. (approx.)
Eyed ova planted in N.Z. waters	1,134,000	or 6 per cent. (approx.)
Fry (immediate and early post-laval fish) released	15,239,000	or 79 per cent. (approx.)
Fingerlings (fish intermediate between fry and yearlings) released	549,000	or 3 per cent. (approx.)
Yearlings (fish of 9 to 14 months) released	33,000	or 0 per cent. (approx.)
Recorded total disposal	17,200,000	or 89 per cent. (approx.)

The balance of about 2,000,000 represents part only of the loss involved in operations, for in many cases the number of fish stated to have been released is

*All quantities of eggs and young fish given here or later in this review should be regarded as approximations only. All are based on data given in official reports of acclimatization societies and of Government Departments or in amplifying communications from officers of such bodies. In many cases, as where releases of fish are identical in number with quantities of eggs collected or purchased or, rarely, where they even slightly exceed them, it is apparent that the data are only sufficient to indicate very approximately the broad lines of operations. Generally, the imperfections of the available data are not such as to render them unsuitable for indicating the approximate extent and nature of activities. The foregoing reservations as to accuracy of data should, without reiteration, be taken as applying to all data on hatchery work, except where more reliable data have been selected for specific purposes and this is stated to be the case.

the same as the number of eggs stated to have been collected or purchased. It will be noticed that acclimatization societies have shown a marked preference for liberating fish as absorption of the yolk-sac is completed. Planting of eyed ova has more recently declined in favour. Further, there is to-day evidence of an inclination to retain and feed a bigger proportion of the fry.

In the three years under consideration, trout eggs were collected from 19 streams which form parts of 12 river systems in nine different acclimatization districts. How the eggs or their products were distributed in the typical year is shown in the summary which follows. Releases in the lower part of the Waikato system are regarded here as being made in a separate system, as falls would preclude any return to the headwaters where ova were obtained.

Total trout eggs collected	19,271,000	or	100 per cent.
(1) Releases in streams trapped	544,000	or	3 per cent. (approx.)
(2) Releases in streams trapped and river systems they enter (includes (1))	5,268,000	or	27 per cent. (approx.)
(3) Total releases in districts where ova collected for sale (includes (1) and (2))	7,417,000	or	39 per cent. (approx.)
(4) Releases in districts where portion of requirements collected locally	1,610,000	or	8 per cent. (approx.)
(5) Releases in districts where no eggs were collected	7,928,000	or	41 per cent. (approx.)
(6) Eyed ova exported	245,000	or	1 per cent. (approx.)

In the three years fish were released into 364 streams and lakes comprising portions of 98 river systems. This total of streams and lakes does not take into account inadequately specified places of release of an average number of 1,529,000 fish each year, or many instances where it seems reasonable to infer that fish recorded as released in one river system or sub-system were, in part, released in unrecorded tributaries. The striking features of these data are, firstly, the great number of streams into which went the product of eggs produced by some of the fish in a few streams, and, secondly, the extremely small percentage of the total taken which was returned to the actual streams from which eggs were collected.

Some further analysis of the operations of different bodies is desirable. The summary, which shows that, on balance, fish released in the districts where ova was collected amounted to 47 per cent. of the number of eggs taken, is based on heterogeneous data. While eggs were collected in nine districts, only 576,000 of a total of 1,721,000 handled in Waimate, Nelson, and Ashburton were obtained locally. In only six of the 24 acclimatization districts in which fish were released were excesses of ova obtained for transfer to other districts. The quantities of ova collected in a typical year and quantities of resultant eyed ova or young fish retained for local release in the six districts are:—

	Ova collected.	Local releases.
Taupo	6,924,000	1,181,000 or 17 per cent.
Southland	4,002,000	2,055,000 or 51 per cent.
North Canterbury	2,977,000	1,051,000 or 35 per cent.
Lakes	1,887,000	827,000 or 44 per cent.
Otago	1,779,000	1,355,000 or 76 per cent.
South Canterbury	1,126,000	948,000 or 84 per cent.
Total	18,695,000	7,417,000 or 40 per cent.

As in several cases local releases, as given, are the differences between numbers of eggs stated to have been collected and numbers sold and given, and in such cases losses have been ignored, it is clear that local releases, considered collectively, must have fallen short of 40 per cent. However, it is sufficient for the present to note that in three districts trapping provided part of the quantities of eggs required; six other districts supplied the whole of the requirements of 21 districts and part of the requirements of three. The loss of eggs to these six districts must have been not less than 60 per cent. of the quantities collected.

It will be of interest later to consider whether the income derived from sale of eggs enabled the selling organizations to release locally more fish per angler or give any additional service. The loss in the separate districts ranged from as high as 83 per cent. to as low as 16 per cent. However, a considerable proportion of the eggs from Taupo went to the adjoining Rotorua area, which is under the same administration, and the percentage sent out of the combined areas was 33 per cent. of the total quantity handled.

Otago drew a small portion of its total supplies from pond stock, and in addition to trapping in its own territory collected eggs from the Lakes District and, from the total handled, returned a portion to the Lakes Society as eyed ova. It sold a further quantity as eyed ova and then released locally about three-quarters of the number collected locally. Included in the numbers collected in the Otago district and released in it and in the Lakes district are quantities handled by the Upper Clutha Angling Association, which trapped fish and hatched the eggs for local distribution.

It is not known why such different percentages of eggs collected were retained by different societies or on what principle they determined what portion should be sold. In general, trapping is carried out in districts where fish enter suitable streams in sufficient numbers and where an experienced staff is available to handle such fish and where a belief exists that it is necessary to operate hatcheries. Where eggs are not collected, it is usually because of difficulties of obtaining supplies locally or because it is considered cheaper to purchase eyed ova and to employ operatives only to hatch them and release the young. The collecting societies attempt to take sufficient eggs to satisfy the demands of local anglers, plus such additional quantity as can be conveniently handled for sale. Sales are effected partly through a desire to oblige less fortunately situated societies, but more because it is thought that costs of trapping and of maintenance of hatchery plant are lessened when a greater quantity of ova is handled and some is sold.

Exclusive of Taupo and Rotorua territories, where special licence fees are charged, and exclusive also of territories where no fish were released, societies between them received £9,791 in fishing-licence fees and planted or released 12,562,000 ova and young fish a year. Thus usual releases of young trout per £1 of licence money amounted to 1,283. In the five districts from which ova were obtained for sale, fishing-licence revenue was £5,473 and ova and young fish retained for local release numbered 6,236,000. Thus in these areas releases amounted to 1,139 per £1 of licence money handled. The remaining 17 districts which purchased ova received only £4,318 from sales of angling licences, yet released 6,324,000 young fish—that is to say, 1,465 per £1 of licence money received.

It was shown earlier that the bulk of the releases were made at the fry stage. It happens that nearly all eyed-ova plantings were by societies which trapped, and most of the fingerlings and yearlings were released by organizations which purchased ova. Thus, in districts where eggs are collected and fewer fish are released, there is no compensation by the liberation of better developed fish.

The general licence fees and the duration of the angling season were the same in all districts under present consideration. There is no conspicuous and general difference in the cost and efficiency of the only other important service—namely, law enforcement, as between the districts where fish are trapped and those where ova are purchased; nor is it evident that, as between the groups of societies adopting these two practices, relatively different parts of income from other sources are employed in fish stocking. **It is clear that, collectively, societies which purchased eyed ova released more fish (if anything, further developed) per angler than those which sold ova, and it does not appear that receipts from sales of ova enabled the vendors to provide any additional services.**

It is important here to note that, in districts where ova are purchased, there is, in the usual case, a definite addition to fish already present of about 1,465 young fish for each angler. Although the number released per angler in districts where ova are collected for sale is about 1,139, neither the whole of this number, nor possibly any part of it, represents an addition to what would have been present if no eggs were collected from fish. This is so because, of the average 100 eggs collected, 60 or so were either sold or died, and only 40 fish were released in local waters. At any time, as has been emphasized by Hutton (1929) and others, the only numerical gain which can result from hatchery operations is the difference between what is actually hatched and what would have hatched naturally. Therefore, in the usual district from which ova were sold, there was a numerical gain only if natural losses would have exceeded 60 per cent., and in such cases the extent of that gain was only the amount by which natural losses would have exceeded 60 per cent.

Later, it will be seen whether or not it is correct to regard 60 per cent. as inclusive of all losses resulting from hatchery work in districts which sell ova. The question of the extent of natural losses will also be considered.

LOSSES IN ARTIFICIAL PROPAGATION

Earlier it was shown what quantity of eggs was handled in a usual operational year, whence these eggs came and whither they went, the number of streams in which they were collected and the number into which resultant fish went, the proportion retained where collected and the number dispatched elsewhere, and the extent of the return made to streams of origin. It was shown that the total number of eggs stated to have been planted and of young fish released was 11 per cent. less than the number of eggs collected. However, as only some societies made a deduction for losses, the total loss must have exceeded 11 per cent. Now it is proposed to inquire further into the question of the usual extent of losses in New Zealand hatcheries. The official reports, which might have provided data for this purpose, are a mixture of those wherein no allowance is made for loss, those where it would appear that a nominal allowance has been made, and—much less commonly—those in which something approaching a careful attempt has been made to ascertain the truth.

Factors which may have militated against the publication of true losses in hatcheries are, in part, probably those inherent in commercial enterprises and in organizations where governing bodies need to satisfy the electors and where staffs in turn need to satisfy such bodies. So long as competitive selling of ova encouraged vendors to show that their offerings were of high quality and so long as a popular demand existed for ever-increasing releases of fish, so long did strong motives exist for suppressing data on heavy losses. Failure to ascertain and publish data on losses cannot be ascribed to these causes alone. In part it would appear to be attributable to the feeling that, as even with the best of care some loss is inevitable, there is no point in parading the fact. The shortcomings of records to which reference has been made are equally evident in the official reports of hatchery operations published by both acclimatization societies and by State Departments.

Where, in what follows, reference is made to heavy losses at particular hatcheries no criticism is intended. Although losses will be shown to vary from hatchery to hatchery, the aim is not to contrast operations carried out in face of different difficulties, but to assemble data which will indicate the extent of losses in the typical New Zealand hatchery.

As later the relative efficiencies of natural and of artificial propagation will be considered, it is proper that all losses incidental to trapping should be taken into account. Relevant losses are all which occur from the time the upstream movement of natural spawners is interfered with until the fish hatched from their eggs have been released.

Losses Incidental to Trapping and Stripping

LOSSES OF MATURE TROUT

In 1941, at the Selwyn River in Canterbury, only 35 fish of over 12,000 spawners which entered the trap are known to have died or suffered serious injury through becoming gilled or entangled in the netting. At Inchbonnie in Westland, in 1934, 6 per cent. of a spawning run of trout, mostly of 13 to 16 inches, were lost in this manner. These latter fish were much below the size usually

handled where eggs are collected, and a greater percentage of eggs than is usual was expressed.

Both personal experience in stripping trout and observation on the handling of trout by seven experienced men have shown that no substantial immediate losses result from the process. Whether fish die subsequently as a result of handling is considered in Appendix C, where it is concluded that there is no satisfactory evidence of permanent injury or subsequent loss.

LOSSES OF EGGS THROUGH INTERFERENCE WITH SPAWNING RUNS

At some major sources of supply of eggs for hatcheries, for instance, the Selwyn, Upukerora, and Eglinton Rivers, only a small portion of the spawning run enters the traps. Yet the upstream movement of greatly more fish than are trapped may be impeded. Data relating to the Selwyn River are considered more fully in Appendix B. In that river in 1941, 28,000 mature trout, which included 20,200 females, had already passed upstream when a trap was installed on 6th June. A further 9,900 females entered the trap and were released upstream by 14th August. **These fish contained more than 60,000,000 eggs. The average quantity of ova taken from the Selwyn during ten years was 2,600,000.**

In usual operational years, the trap, or a preliminary barrier, was installed early in May. Unless floods permitted fish to escape upstream, the trap was usually maintained into July. In some years a fence was put across the stream for a further period after the trap was removed. Thus, often for a period of two months, trout, which were reluctant to enter the trap, were held below it. The area below, available for natural spawning, was so restricted that the same portion of the bed was dug over and over again by successive waves of spawners. Many fish may have spawned completely below the trap. Those which entered it had usually shed a third of their eggs. It is possible that the quantity of eggs jeopardized each year by the enforced deposition of eggs under conditions unfavourable to survival was as much as 20,000,000.

In the Upukerora in many years, a rack to stop upstream migrants was installed, when possible, in March and was maintained, floods permitting, until mid-August. This rack was within half a mile of Lake Te Anau, from which many hundreds of Atlantic salmon and some thousands of brown trout entered to spawn. It prevented their natural dispersal over many miles of river. April and May are the peak months for the salmon runs. The run of brown trout develops slowly to reach a peak possibly as late as July or August. Some spawners entered a trap below the rack. Many others delayed below to spawn in the restricted areas downstream. Of these, a proportion were netted off spawning redds and were stripped. Eggs of the first spawning species, the salmon, and of the earliest running trout were jeopardized by the enforced concentration of late spawners where others had spawned earlier. This was the position in years most favourable to natural spawning. Only in years when very severe flooding breached the rack were spawners able to disperse upstream.

It is not known how general are conditions such as those described in the Selwyn and Upukerora. However, the quantity of eggs jeopardized in these two

rivers in a trapping season possibly often exceeded the peak intake of eggs by all New Zealand hatcheries of about 20,000,000.

WASTAGE OF EGGS OF FISH TRAPPED AND STRIPPED

The general effects of trapping on whole spawning runs and the nature of conditions below traps and the possible extent of the ensuing loss have been indicated. More definite data are available as regards the smaller number of fish actually trapped and stripped. It is shown in Appendix B that such fish in the Selwyn yield to the strippers greatly less than their total production of eggs. In the Upukerora and Eglinton in Southland, most fish handled are partially spent. The yield in the Selwyn is less, because approximately one-third of the eggs have been shed below the traps under conditions which afford a very slight chance of survival. It is also less because approximately 11 per cent. of the eggs the fish contain when they enter the trap are not removed by stripping. There is no evidence that the trout attempt to spawn these residual eggs, and, as the stripped fish are released below the traps, the eggs would have a very poor chance of surviving if they were deposited.

Losses in Hatcheries

No data are available from which the extent of losses in New Zealand hatcheries generally could be ascertained with precision. It is not the practice to publish each year data on losses at any one hatchery. It is not possible, therefore, to study losses at a number of typical hatcheries over a sufficient series of years to show the normal variation in loss. In many cases releases of fish are stated to equal in number the eggs collected or purchased. Only sometimes, when the releases are stated to be fewer than the number of eggs handled, does it appear that a reasonably careful attempt has been made to determine the extent of loss. For instance, it has been necessary to avoid periods where releases vary from year to year from quantities sometimes even in excess, sometimes the same, and sometimes less than the quantities of eggs received. Again, sometimes a figure has been given for total losses, without differentiation, where the hatchery products have been disposed of in part as eyed ova, in part as fry, and in part as older fish. Despite the imperfections of many official reports, examination of a large number has brought to light data of considerable indicative value. These data are presented subject to the comment that, for reasons to be given, the estimates of average loss derived from them are likely to be conservative.

For business purposes, a number of supplying societies have made a practice of adding 10 per cent. or more to the quantities ordered. Purchasing societies do not object to this, and in many cases may be unaware of it, as their official records usually mention the quantity ordered rather than the larger quantity usually received. A consignment examined by the writer proved to be 23 per cent. in excess of the quantity ordered. The Whangarei Society informs me that three of four consignments ordered in 1938 were each 10 per cent. over and the other 12 per cent. over the quantity ordered. These consignments came from three different suppliers.

It will be evident that where the quantity of fry produced is measured, the difference between this number and the number of eggs ordered will be less than the actual loss if surplus eggs have been supplied. Eggs are purchased at the eyed

stage. Subsequent losses, as given later in this section, are frequently based on the difference between numbers of eggs ordered and of fry produced. They are, therefore, possibly under-estimated.

A further point arises. Whence come the additional eggs, where recorded total collections balance the sum of sales, local disposals and losses, and the quantities stated to have been sold are under-stated by 10 per cent. or more? Observations showed that some years ago, at one major supplying station, the quantity of eggs collected was always grossly under-stated, so that a good margin was provided to cover some of the loss up to the eyed stage, and to enable good measure to be given to purchasers. In this particular case, receipts of eggs were actually 25 per cent. in excess of the quantity recorded. To what extent this practice was general, or still obtains, is not known.

An extreme case of falsification of records occurred when I gave a carefully measured quantity of fry to an employee of an acclimatization society. He reported to his council that he had received double the quantity I gave him. The council, in its annual report to the anglers, doubled the quantity again, so that an original quantity of 25,000 became 100,000. There is no evidence that practices as extreme as this are general. There are grounds for regarding the figures for loss given later on as more likely to be under-stated than over-stated.

Where adequacy and apparent reliability of reports have made it possible, losses are given for two or more consecutive years for each district during the period 1930–40. In some cases data on losses in recent years have had to be supplemented by reference to earlier reports. With certain exceptions, references given are to official annual reports of acclimatization societies for years ended 31st March. Thus "Otago/37" means the report of the Otago Acclimatization Society for the year ended 31st March, 1937—a period which covers hatchery operations in the winter and spring of 1936 and any subsequent rearing of fish through the summer of 1936–7. The exceptions, where information was supplied in personal communications from responsible officers of societies, are indicated by asterisks.

Losses extraordinarily heavy for any particular hatchery have been excluded at this stage, as it is desired first to consider losses under normal conditions. Subsequently, the frequency of abnormal losses will be considered.

EXTENT OF NORMAL HATCHERY LOSSES

Losses of Pre-eyed Ova.—In districts where eggs are collected, they are held until the most vulnerable stage of development is past and the pigmented eyes can be seen. They are then subjected to shock, usually by being dropped about three feet into water. Weak eggs are killed in this process, and many of the infertile eggs present become opaque and may readily be separated. The losses considered here are of all ova dying before eyeing and those removed shortly following testing. Data on these losses are given in Table XII.

TABLE XII

	Percentage per annum.	District mean.	Mean for species.
Pre-eyed Ova of Brown Trout—Loss:			
Otago, /37	7.9 per cent.	8.3	
Otago, /38	8.8 per cent.		
Southland, /26	24.3 per cent.	20.3	
Southland, /27	19.8 per cent.		
Southland, /28	13.9 per cent.		
Southland, /36	23.3 per cent.		
North Canterbury, /34	5.6 per cent.	5.7	10.5
North Canterbury, /35	5.9 per cent.		
South Canterbury, /33*	11.9 per cent.	7.9	
South Canterbury, /34*	6.5 per cent.		
South Canterbury, /35*	7.1 per cent.		
South Canterbury, /36*	8.8 per cent.		
South Canterbury, /37*	5.4 per cent.		
Pre-eyed Ova of Rainbow Trout—Loss:			
Otago, /29	6.9 per cent.	9.8	9.9
Otago, /35	12.7 per cent.		
South Canterbury, /34*	6.7 per cent.	10.1	
South Canterbury, /35*	6.9 per cent.		
South Canterbury, /36*	10.7 per cent.		
South Canterbury, /37*	16.3 per cent.		

The Otago figures for losses of brown trout in 1937 relate to eggs taken from pond stock and from the Leith Stream. In 1938 they include also losses at Lake Hayes, in Central Otago, where in recent years the bulk of the supplies was obtained. Probably 8.3 per cent. would be below the average for the ten-year period, as heavy losses are said to have occurred when the present hatchery was first used.

In Southland, eggs of brown trout were collected from the upper portions of the Waiau River system.

North Canterbury drew its supplies very easily from the Selwyn River. As will be shown later, these figures are based on results in abnormally favourable operational years.

In South Canterbury, operations were on a smaller scale than in the three preceding districts. This society, unlike the other three, did not usually supply outside districts.

The great bulk of the rainbow eggs comes from a district which did not publish data on losses. The figures given relate to relatively small quantities. The Otago rainbow ova in 1935 had travelled an unusually long way in the "green" state. The losses, as given for 1929 there, are exclusive of an additional 16.7 per cent. lost through some unspecified mishap.

It would appear from the foregoing that losses of pre-eyed ova of brown trout vary under the different conditions encountered in the three main supplying districts from possibly as little as 5.5 to 14 per cent., even in the most satisfactory years. Usually, losses in different districts range up to at least 20 per cent. from a figure possibly as low as 8 per cent., but certainly higher than that shown for North Canterbury. Because a number of cases of heavy loss have been excluded, the general figure of 10.5 per cent., taken as a mean for eggs of brown trout in New Zealand hatcheries, is a conservative estimate of loss before eyeing. The fewer data relating to eggs of rainbow trout show a mean of about 10 per cent.

The reports of the Ballarat Fish Acclimatization Society, of Victoria, Australia, for 1933 and 1934, show losses before eyeing of 13.6 and 23 per cent. respectively for eggs of brown trout and of 36.3 and 23.5 per cent. respectively for rainbow. There, it is necessary to obtain many eggs by netting spawners in lakes and reservoirs rather than all from the trapping of running fish as in New Zealand.

Losses of Eyed Ova and of Alevins (larval fish).—With few exceptions, the following figures relate to eggs which have been transported from other districts while in the eyed stage. What portion of the eyed stage had elapsed in each case prior to transportation is not known. The exceptions are the rainbow trout eggs handled by Otago in 1938 and some of the brown trout eggs handled in the same district in each of the three years. The North Canterbury rainbow loss of 1936 is based on a handling of three lots of eggs, and may include pre-eyed losses in one of these lots which was collected locally. However, the stated percentage loss on this lot agrees closely with the percentage difference given here between total eggs received and total fry released.

The figures for Whangarei result from careful checking of quantities received and the counting of all subsequent losses. In Auckland, also, all dead were carefully counted. In most other cases the figures represent the amount by which recorded disposals of fry were less than recorded receipts of eyed ova. Losses are set out in Table XIII.

TABLE XIII

	Percentage per annum.	District mean.	Species. Mean for
Eyed Ova and Alevins of Brown Trout—Loss:			
Otago, /31	10.6 per cent.		
Otago, /33	18.7 per cent.	12.7	
Otago, /34	8.8 per cent.		
Wellington, /27	7.4 per cent.		
Wellington, /28	7.2 per cent.	6.1	
Wellington, /30	2.5 per cent.		
Wellington, /31	7.1 per cent.		15.6
Auckland, /37	35.5 per cent.		
Auckland, /38	7.7 per cent.	25.4	
Auckland, /39	33.1 per cent.		
Whangarei, /38*	18.7 per cent.	18.3	
Whangarei, /39*	17.9 per cent.		
Eyed Ova and Alevins of Rainbow Trout—Loss:			
Otago, /29	18.4 per cent.		
Otago, /37	10.0 per cent.	12.6	
Otago, /38	9.5 per cent.		
North Canterbury, /34	3.7 per cent.		
North Canterbury, /35	10.7 per cent.		
North Canterbury, /36	20.5 per cent.	12.4	
North Canterbury, /37	18.0 per cent.		
North Canterbury, /38	11.3 per cent.		
North Canterbury, /40	10.0 per cent.		
Wellington, /27	6.7 per cent.		8.8
Wellington, /28	11.7 per cent.	5.8	
Wellington, /30	2.5 per cent.		
Wellington, /31	2.5 per cent.		
Auckland, /38	2.1 per cent.	5.8	
Auckland, /39	9.5 per cent.		
Whangarei, /39*	6.2 per cent.		
Whangarei, /40*	8.8 per cent.	6.6	
Whangarei, /41*	4.8 per cent.		

Losses of brown trout ova and alevins in Otago may have been heavier than usual in 1931 and 1933 because of difficulties with the water supply when the new hatchery was opened. However, losses of rainbow in the same district in two more recent years and at an earlier hatchery in 1929 give a similar average.

Very heavy losses of brown trout are shown at Auckland in two of the only three years for which data are available. These are exclusive of a 25 per cent. loss in transit in 1937. These losses are not ascribed to any unusual happening, such as failure or contamination of water supply. Foerster (1938), in the case of sockeye salmon, and Pritchard (1938), in the case of pink salmon, have both recognized that, for no readily apparent cause, hatchery losses may be much heavier in some years than in others. With brown and rainbow in New Zealand a considerable variation in loss from year to year occurs, and, except in extreme cases, reports are silent as to causes.

The heavy loss of brown trout at Whangarei in 1939 is ascribed to "blue-swelling" among alevins hatched from one of two consignments of eggs received. This is a usual cause of some loss in most New Zealand hatcheries each year and an occasional cause of very heavy loss.

In all, data relate to losses in the production of fry from 30 lots of eyed ova. Ova of both species of trout have been handled regularly for many years in most districts. Although more data are sometimes available at some stations than at others, it has seemed advisable to give data from each district an equivalent weight in arriving at a general figure. The mean loss in the production of fry from eyed ova is 15.6 per cent. for brown trout and 8.8 per cent. for rainbow trout.

The variation in loss shown, even from season to season at one station in the case of one species, suggests the need for caution in concluding that rainbow are easier to produce. The reports of the Ballarat Society for 1933, 1934, 1935, and 1936 show that, in the raising of rainbow fry from eyed ova, losses were 14 per cent., 8 per cent., 4 per cent., and 10 per cent. respectively; for brown trout in the same years losses were 18.7 per cent., 1.6 per cent., 2.5 per cent., and 5.3 per cent. respectively.

Reports were collected by Fish (1939) of losses of eggs and young fry of brown and of rainbow trout in a series of United States hatcheries. His data relate to quantities in excess of 12,000,000 ova of brown trout and over 35,000,000 of rainbow. Losses of ova before hatching amounted to 6.5 per cent. for brown trout and 17.6 per cent. for rainbow. With additional losses before the completion of larval development, 8.7 per cent. and 24.7 per cent. of the original quantities of eggs of brown and of rainbow trout respectively had been lost. In many instances, losses prior to arrival at hatcheries, possibly as eyed ova, are not included, although such losses were considered by Fish to be small. Further, cases of "unaccountable" loss and of losses through "accidental" causes were excluded.

Undifferentiated Losses to Fry Stage.—Losses from the time of collection of eggs of brown trout until fry were released were carefully recorded in the Ashburton district during the year ended March, 1933. The total loss as given by Harle and Kemp (1936) was 11.3 per cent. This figure is much below the average for New Zealand hatcheries indicated by data already produced. As will

be seen, when abnormal losses are being considered, it was also much below the average for the Ashburton hatchery.

Reference has been made to very low losses before eyeing at the North Canterbury hatchery in 1934 and 1935. Reports over a number of years show that there quantities of eyed ova and fry of brown trout disposed of were less than the quantities of eggs received by the following amounts: 1932, 15.5 per cent.; 1933, 8.3 per cent.; 1934, 5.9 per cent.; 1935, 14.6 per cent.; 1936, 5.6 per cent.; 1937, 62.5 per cent.; 1938, 16.1 per cent.; 1940, 26.8 per cent. No brown-trout eggs were hatched in 1939. In the other eight years approximately half the hatchery product of brown trout was disposed of as eyed ova. Therefore, the figures given, being based on hatchery intakes, represent a portion only of the total loss up to the fry stage. Even so, they show an average annual loss of 19.4 per cent. What the total loss would be is not known, but if the percentage losses before and after eyeing were the same, 19.4 per cent. would represent about three-quarters of a total loss of 26 per cent. The assumption on which this estimate is based is one which data given earlier suggest should give a conservative result.

ABNORMAL LOSSES

As has been shown by data relating to the North Canterbury and other hatcheries, losses vary in extent from year to year and occasionally reach calamitous proportions. As the operation of hatcheries in this country dates from as early as 1867, heavy losses cannot be attributed wholly to want of experience, and may be expected to continue to occur from time to time. They must therefore be taken into account in an appraisal of the hatchery system. From the tables of losses given earlier there were excluded cases of (a) heavy loss of eyed ova in transit, (b) heavy loss attributable to failure of water supply or to the contrary cause—namely, unforeseen flooding, and (c) losses in the sense that unforeseen circumstances frustrated the carrying out of a desired plan of releasing fish. Cases of heavy loss recorded in reports of societies from whose districts other data have been used are given below. The list is not necessarily comprehensive.

(a) A quarter of a consignment of 200,000 eyed ova of brown trout, ordered by Auckland in 1937, died before reaching their destination. Percentage losses as given earlier for that year are based on the quantity which arrived alive.

In the following year Ballarat reported the loss of a box of 30,000 out of a consignment of 450,000 from New Zealand.

The Otago loss of rainbow eggs in the pre-eyed stage, at 6.9 per cent. in 1929, is exclusive of a loss of 16.7 per cent. of the total handled, their further loss being described as of a quantity intended for Ballarat. Losses of eyed ova in transit are made good usually by the vendor, and when replaced during the same year are commonly not recorded in reports.

(b) The lowest pre-eyed losses listed earlier were those at North Canterbury in 1934 and 1935. There, in 1937, losses before the fry stage was reached exceeded 62.5 per cent. This heavy loss was attributed to failure of water supply.

At Ashburton, losses of ova and alevins, already referred to, in the year ended March, 1933, were as low as 11.3 per cent. However, the following year Ashburton reports showed that all rainbow fry were lost or escaped during a flood. In 1935 a total loss of brown-trout ova occurred. In 1936, 1938, and 1939, no unusual

losses were recorded, but in 1937 the loss, through accident, is noted of 100,000 fry out of a total of 395,000.

Data have been given on losses to the fry stage at the Whangarei hatchery for each of four years. After such determinations had been made in 1939, there was a loss of about one-fifth of the hatchery product which was being retained for further development. This was apparently attributable to contamination of water supply.

In Otago, where pre-eyed losses have been given for the satisfactory operational years of 1937 and 1938, a "severe" loss of unstated proportions was recorded in 1931. This was attributed to silting, a trouble easily remedied by washing in the case of eyed eggs and therefore unlikely to have influenced the extent of post-eyed loss presented for 1931.

In 1939, in North Canterbury, flooding interfered with the water supply, and it became necessary to dispose of all brown-trout eggs at the eyed stage. Thus the intention of the society of following its usual practice of distributing about half of the hatchery product locally was frustrated.

Auckland reported escapages, into waters other than those intended, of 20 per cent. in 1936 and 55 per cent. in 1937 of fish retained for release as fingerlings.

A case of loss or escape of all rainbow fry at Ashburton in 1939 has been mentioned.

It is a not unusual happening for difficulties, arising during the transportation of fish for release, to necessitate the diversion of portion of the load to waters other than those originally intended.

These cases of frustration of purpose do not necessarily result in any additional mortality, and are thus distinguishable from losses proper, listed earlier. However, it seems right to notice that the operation of hatcheries does not always enable quantities of fish required to be released where desired. Additional evidence of this is afforded by reports of a major purchasing society. Wellington reports for the ten years 1930–39 show that in at least four years quantities of eggs of brown trout which could be supplied were considerably less than those ordered. Extremes of weather, either flooding or very low water, accounted for the failure of the supplying societies to obtain eggs needed. Endeavours on the part of the suppliers to keep faith with their customers often resulted in fewer eggs being retained for local hatching than had been intended.

LOSSES IN REARING FINGERLINGS AND YEARLINGS

Certain societies retain, for release at greater sizes, some of the fry produced at their hatcheries. Except in the case of the Auckland society, the figures given below are not claimed, in the respective reports, to result from careful counting of fish. The percentage losses are in some cases based only on approximate numbers of fry stated to have been held for rearing.

Not uncommonly, the survivors of fry put into ponds in late spring are described as yearlings when released in the autumn. Where it has appeared necessary, inquiry has been made as to the actual period of retention. Such periods, as given below, should be regarded as approximations. Data relating to operations of like duration at any hatchery in successive years are bracketed. In addition to data from official reports, use has been made of data (privately communicated to me)

as to losses in two lots of brown trout reared in the Wellington district in 1939–40 by local co-operatives. Losses of brown trout held after absorption of yolk-sacs for different periods are shown in Table XIV.

TABLE XIV

Report.	Approx. period.	Percentage losses.	
Auckland, /39	3½ to 4 months		30.1
Otago, /34	3 to 5 months		50.8
Otago, /33	4 to 5 months	67.6	
Otago, /35	4 to 5 months	64.3	Av. 65.3
Otago, /36	4 to 5 months	64.1	
Auckland, /38	5 to 6 months		62.1
Wellington, /29	5 to 6 months	68.5	
Wellington, /30	5 to 6 months	60.0	Av. 62.8
Wellington, /31	5 to 6 months	60.0	
Wellington, /39–40	10 months		78.7
Wellington, /39–40	11 months		86.7

The mean length of fish produced probably ranges from about 2 in. for the shortest period up to about 3 in. at six months.

Having regard to the different conditions at different stations, a surprisingly consistent increase in loss with age is shown. Heavy though these losses are, reference to data from other countries shows that similar losses are usual. Armistead (1908) states that fry hatched from eggs taken from wild parents are, though strong and healthy, difficult to rear, and that a man will be lucky indeed if he succeeds in bringing 30 per cent. to yearlings. Coston and others (1936), also speaking of the rearing of brown trout in England, say that most hatcheries reckon to have had a good year if they rear 5 per cent. of the fry to the yearling stage. Fish (1939), reporting on data supplied from five United States hatcheries, found that the loss of brown trout from the time the yolk-sac was absorbed until a length of 2½ in. was reached was about 20 per cent. In British Columbia, Mottley (1935[1]) recorded a loss of 29 per cent. of fry retained until they reached three inches.

In Australia, over a long period of years, the Ballarat Fish Acclimatization Society has kept very careful records of loss in the rearing of fry to yearlings. In the 18 years beginning with 1920, quantities of from about 15,000 to 97,000 in different years have been successfully reared for release in the winter or spring following hatching. Losses have ranged from as low as 55 per cent. to as high as 83.6 per cent. The average annual loss has been approximately 71 per cent.

In New Zealand, losses are shown to exceed 60 per cent. in five or six months, and seem likely to reach 80 or 90 per cent. in 12 months under conditions usual in this country.

Data given in Table XV suggest that the rearing of rainbow is somewhat easier.

TABLE XV

Report.	Approx. period.	Percentage losses.	
Auckland, /39	3½ to 4 months		5.4
Wellington, /29	5 to 6 months	45.0	
Wellington, /30	5 to 6 months	22.0	Av. 23.7
Wellington, /31	5 to 6 months	4.0	
Auckland, /38	5 to 6 months		38.0

In the United States, Fish (1939) reported a loss of about 20 per cent. by the time a length of $2\frac{1}{2}$ inches was reached, rising to about 25 per cent. at 4 inches.

In England, Worthington (1941) states that with rainbow a 50 per cent. loss from fry to yearlings is usually experienced.

In Australia, reports of the Ballarat Society, for the same period of 18 years considered earlier, show that losses in different years ranged from 24.5 per cent. to 78 per cent. in rearing rainbow fry to about the yearling stage. The average of losses in all years was approximately 60 per cent.

Comparison of data relating to the rearing of brown and rainbow brings to light two interesting differences. A greater variation in losses is shown in the case of rainbow. The raising of both species at the same New Zealand establishments in the same years and over the same period at Ballarat has shown that losses are fairly consistently lower in the case of rainbow. English sources also report greater losses in rearing brown trout. Less though the losses may be with rainbow trout, it is apparent that, under present conditions, very high percentages of both species usually die if held in captivity.

It is widely appreciated that artificial ponds afford trout protection from large enemies. It is less commonly appreciated that pond-rearing involves unnatural feeding. Further, it involves the crowding of fish to a degree very abnormal by natural standards and thereby conditions are created especially favourable for the spread of parasites and disease and favourable also to high incidence of cannibalism. **There is a danger of excessive emphasis being attached to the one certain benefit of pond-rearing and of too little attention being given to its possible disadvantages.**

Large fish are usually considered to have a greater chance of surviving than small fish have. Yet large fish cost so much more to produce that it is questionable whether, on balance, any gain results from the production of fewer large fish instead of many smaller fish. Mottley (1935[1]), in British Columbia, has shown that brown trout of 3 inches cost about 14 times as much per 1,000 to produce as fry do. That is to say, for a given sum, there would have been produced either 100,000 fingerlings or 1,400,000 fry.

A practice has developed in parts of the United States of releasing fingerlings in intensively fished waters and fry in remote waters. Unless the practice is adopted to assist the quick restoration of stocks destroyed by flood or other cause, it would not appear to have any logical basis.

DISPOSAL OF FISH—LOSSES IN TRANSIT

Two societies have gone to some trouble to learn what loss occurs during the transportation of fry from the hatcheries to various streams and lakes.

North Canterbury reports that in 1936, in the disposal of 1,000,000 brown-trout fry, there was a loss of approximately 68,350 or 6.8 per cent. The loss on consignments to 19 localities varied from about 2 per cent. to 6 per cent., and on a further lot reached 25 per cent. Of 434,000 rainbow fry dispatched to nine localities, 11,100 or 2.6 per cent. failed to survive. The same society in 1938 reported the dispatch of 443,500 rainbow fry to different parts of its district for a loss of about 18,970 or 4.3 per cent.

Auckland in 1938 recorded a loss of 6,908 or approximately 1 per cent. of

715,000 fish distributed. This number, apart from a small quantity of brown-trout fry, consisted of rainbow fry and fingerlings in about equal numbers. The Auckland transportation loss is low, largely because most long-distance deliveries are made at night. The hatchery is left at such a time that, with fast travelling, the area of release will be reached near dawn. This admirable Auckland practice, which is to some extent necessitated by higher temperatures encountered in the north, is not general in New Zealand. Data from North Canterbury, where, as in most other parts, fish are transported by day, seems more indicative of usual losses. The average of the four figures given, including Auckland—6.8 per cent., 2.6 per cent., 4.3 per cent., and 1 per cent.—is 3.7 per cent. This is probably a conservative estimate of the transportation loss in the average district.

THE TOTAL OF LOSSES

It is not possible to estimate with precision the total losses suffered in the course of operations incidental to the production of fry in New Zealand hatcheries. The various figures reached are helpful, as far as they go, but they do not give a comprehensive picture of losses.

Losses have so far been spoken of as percentages of the numbers available at the beginning of each operation or stage. To summarize them, it will be necessary to consider their relationship to the number of eggs originally available and express all losses as percentages of the number of eggs contained in fish entering the traps. Operations in New Zealand fall largely into three categories, according as (a) green eggs are collected solely for local use, (b) green eggs are collected partly for local use and for partial development before sale as eyed ova, and (c) eyed ova are purchased.

In Table XVI, results are set out in different ways for the convenience of organizations adopting different practices. Eggs brought into the trap are taken as 100 per cent. where collections are made. Eggs purchased are accorded this value elsewhere. Figures are also given for losses on the basis of the number of eggs which ripen in fish subsequently stripped. No account is taken of losses of adult fish through trapping nor of losses of eggs of fish held below traps, which are not actually handled in the traps.

TABLE XVI

	Available ova: In ripe fish.	In fish trapped.	Where eyed ova purchased.
Total ova	100%	.....	.....
Eggs shed below trap (33%)	33	.....	.....
Ova available at trap	67	100%	.....
Loss in imperfect stripping (11%)	7	11	.....
Green ova to hatchery	60	89	.....
Loss of pre-eyed ova (10%)	6	9	.....
Eyed ova obtained	54	80	100%

Loss of eyed ova and alevins (12%)	6	10	12
Fry for distribution	48	70	88
Loss in distributing fry (4%)	2	3	4
Live fry released	46	67	84
Total loss	54	33	16
Totals	100%	100%	100%
Fry released locally where 50% of eyed ova sold	23	34	.....
Then total loss	77%	66%	.....

DISCUSSION

So often has it been stated, both abroad and in New Zealand, that the loss in hatcheries is about 5 per cent that the figures given may seem surprisingly high, even if the loss through incomplete stripping is ignored. Imperfect though the evidence on extent of losses in New Zealand may be, it is likely to be more reliable than assertions for which supporting data are not produced. Credence is lent to conclusions as to local losses by data produced as to losses abroad.

In New Zealand, losses of ova of quinnat salmon before hatching were 14.5 per cent. in 1939 and 10 per cent. in 1940. In 1939 the total hatchery loss in the production of free-swimming salmon fry was 17.6 per cent.

Reference may be made to the hatching of eggs of two closely related species in Canada. Data given by Foerster (1938[1]), concerning sockeye salmon (*O. nerka*), show that in one year 8.2 per cent. and in another 6.5 per cent. were lost when green eggs were collected and held until eyed. In three other years free-swimming fry were produced, and the total losses in different years amounted to 8.8 per cent., 20.2 per cent., and 11.2 per cent. of the numbers of eggs collected. Pritchard (1938) has recorded losses in the hatching of pink salmon (*O. gorbuscha*). His data (after deduction of quantities removed for experimental purposes) show losses, up to and including the commencement of eyed development, of 15.3 per cent., 18.7 per cent., and 19.4 per cent. of the quantities of green eggs laid down in different years. In the first and third years, respectively, eyed eggs were retained and hatched with further losses of 6.8 per cent. in the first case and of 7 per cent. in the last year of the number of eggs collected. Thus losses in the production of free-swimming fry from green eggs were 22.2 per cent. in the one year and 26.4 per cent. in the other.

When the production of yearling quinnat salmon was required at the Hakataramea Hatchery in New Zealand, the usual practice was to allow 20,000 fry for each 6,000 yearlings required. Thus provision was made for a further loss of 70 per cent.

Data should not be taken as giving more than an approximate picture of losses in the typical hatchery in New Zealand. Losses are known to be higher usually at some hatcheries than at others and to vary from year to year at all of them. Because certain instances of exceptional loss were excluded from the data on

which those estimates were based and for other reasons already given, it seems probable that these estimates are on the conservative side.

Two reservations must be made about the figures based on quantities of eggs originally in fish which later were trapped. It is not known how generally such substantial depositions of eggs, as in the Selwyn, occur below traps. Further, while it is known that wastage of eggs occurs in such places, it is not known what proportion of the eggs is wasted. **A safe conclusion is that where fish trapped for local needs between 33 per cent. and 54 per cent. of their eggs are usually wasted before free-swimming fry are produced. Where sales of eggs are effected, the percentage of the original quantity of eggs returned to local waters as free-swimming fry is still further reduced.** For instance, if 50 per cent. of the eyed eggs were sold, then losses and sales would effect a reduction of between 66 per cent. and 77 per cent. respectively of the eggs originally available in the trap, or available earlier in fish which subsequently entered the trap. Where eyed ova are purchased, usually a loss of not less than 16 per cent. occurs by the time free-swimming fry are released.

If fry are retained and fed until the following winter, then, in the case of brown trout, about 80 per cent. of them would be expected to die. Thus survivors would amount to about one-fifth of the quantities of surviving fry given in Table XVI: that is to say, to 10 per cent. to 14 per cent., where locally collected eggs are all retained for local use, or 5 per cent. to 7 per cent. where half the eyed ova are sold, or to 18 per cent. of the quantity of eyed ova purchased, where this practice is followed. With rainbow trout the probability is that losses would usually be lighter.

It will be observed that, especially where fry are released, there is a striking difference in the results to be expected from the two usual New Zealand practices—namely, of collecting eggs locally and selling a substantial proportion at the eyed stage and of purchasing eggs at the eyed stage. In the former case, if half are sold, a district loses 66 per cent. to 77 per cent. of the initial number of eggs. In the latter case, a district gains about 84 per cent. of the initial number of eggs with which it is concerned. In both cases operation give societies the advantage of being able to release the survivors where they want them. Where eggs are purchased, the fish produced from them represent a numerical gain to the district of release. But where eggs are collected solely or in part for local use, there is a numerical gain to the district concerned only if, and to such extent as, losses resulting from collecting, hatching, and selling are less than the losses which would have occurred if spawning runs had not been interfered with. It is convenient at this point to consider the extent of losses in natural reproduction.

LOSSES IN NATURAL PROPAGATION

The results of studies of natural reproduction of trout and salmon in New Zealand have been set down in detail by the author (1937 and 1940) in Bulletins 6 and 8. It is therefore necessary here to give only a summary, which may be amplified by reference to these papers, and to add data on a few points not covered by earlier papers. Questions arise as to:

(1) What proportion of the eggs which ripen in fish are extruded?
(2) What proportion of the eggs extruded are satisfactorily deposited in redds?
(3) What proportion of the eggs so lodged remain there, hatch, and produce free-swimming fry?
(4) What proportion of eggs or larval fish are dislodged from redds before completing their development?

EGGS NOT EXTRUDED

Fourteen female trout, trapped as they returned downstream after spawning naturally, were killed and found to have retained in all 95 eggs. A like number of fish of the same sizes, all with firm ovaries, were killed in the same stream as they went upstream towards spawning areas. These fish contained over 15,000 eggs. The number of eggs retained by the natural spawners was therefore approximately 0.6 per cent. of the number they are estimated to have produced.

EGGS NOT LODGED

Two pairs of brown trout were released, a pair at a time, into an area of their chosen spawning stream from which other spawners had been excluded. The productivity of other trout comprising the same run was studied. The fish released were kept under observation. When they had finished spawning, the redds made by them were excavated and the eggs dug from them were collectd in a net. Eggs recovered amounted to 96.5 per cent. and 98.5 per cent. of the average number produced in that stream by fish of the respective sizes of those released.

Experience has shown that complete recovery of all eggs deposited is seldom practicable and that some escapage round the net or re-burial is usual. The number of eggs unaccounted for is, at 2.5 per cent., well within the limits of variation in production shown by different fish of like size, and therefore does not necessarily indicate loss. This figure includes eggs retained by both fish, estimated at 0.6 per cent. Thus the loss attributable to non-lodgment alone might be about 2 per cent.

The presence of small trout, and sometimes of eels, immediately below redds on which trout are working, and the occasional recovery of substantial numbers of eggs from their stomachs, may suggest probabilities of loss greater than that indicated here. However, here we are concerned solely with losses arising from failure of eggs to lodge at the time of spawning, and not with losses of eggs occasioned when other fish, in making their redds, disturb eggs deposited by earlier spawners. Such losses, which will be considered later, are additional to those at present under consideration.

LOSSES IN REDDS

Observations as to what losses take place subsequently to the completion of spawning have been made in 77 streams, including most of the types with which New Zealand anglers are familiar. They include fairly turbulent hill-country streams and others flowing quietly across plains; those in heavy and those in light rainfall areas; some in virgin bush and others in deforested country; spring creeks of fairly even flow and temperature; and rivers with extensive flood-beds and variable flows and temperatures. Many flowed over gravel of rounded greywacke, others over gravels of softer sedimentary rocks, or of pumice and rhyolite, schist, quartz, or granite.

CONSTRUCTION OF SPAWNING REDDS OF BROWN TROUT

Trout prefer to spawn where there is a moderate current over relatively stable gravels, usually to 2 in. in diameter, moderately consolidated with finer binding materials. Trout avoid loose, clean shingle. While they can move very consolidated underlying material, they avoid areas where surface stones sit, as it were, "waist deep" in embedding silts. The gradient of the ground selected should be fairly uniform in cross section and not too steep in a downstream direction; indeed, a fairly level bed or one which rises a little towards the tail end of a pool is commonly used. The site is chosen by the female, which alone makes the excavation and buries the eggs.

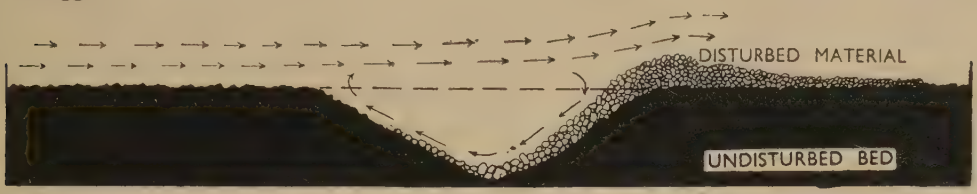


FIGURE II

Longitudinal section of redd under construction, showing the basin-shaped depression in which eggs are laid. Water passes rapidly over the top of the redd, but in the hollow eddies slowly upstream. The eggs, which at first are adhesive, lodge in a fairly compact mass among the coarser stones in the bottom of the pit, where they are fertilized by the male. The eggs are then covered, apparently, before they lose their adhesive quality. Eggs are not seeded evenly through the gravel, but are concentrated in one or more such pockets, usually 8 in. to 10 in. below the surface of the surrounding bed.

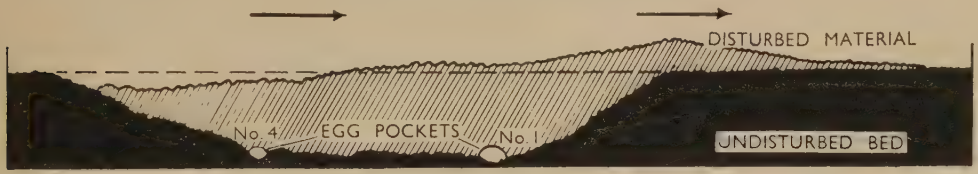


FIGURE III

The same redd when completed: two of the four pockets made were on the same axis, and are shown. The completed redd is a depression of highly permeable gravel, from which fine material has been washed, in a surrounding area of relatively impermeable material. Percolating water bears oxygen to the eggs. Progressively, as a redd ages, the depression tends to resume the character of the surrounding bed. Sediment settles among the surface stones, and will do no harm unless it penetrates in substantial quantity to the eggs.

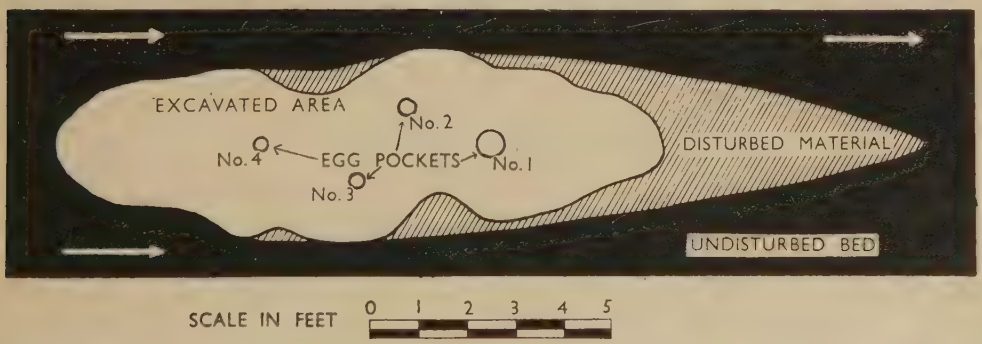


FIGURE IV

This is a plan of the same redd as in Fig. III, and is approximately to scale. It is based on measurements of a redd left above water as a stream dried up. The total area excavated was about 12.5 ft. x 3.3 ft., although the over-run of shingle extended another 3 ft. or 4 ft. The pockets, numbered 1 to 4, in order of digging from the downstream end, contained respectively 1,030, 443, 315, and 249 eggs. These pockets averaged 25 square inches in extent, and together occupied about one-sixtieth of the area excavated. Only three eggs were found outside the pockets. In the Selwyn River in Canterbury, the number of pockets in 14 redds varied between 1 to 6, with a mean of 3.4. These redds, each apparently the work of one fish, varied in length from 3.3 ft. to 19.2 ft., in width from 2 ft. to 4.5 ft., and averaged 30 sq. ft. in extent. It is known that trout often make more than one redd in a season. This and the difference in size of fish (usually 2 lb. to 6 lb. in the Selwyn) probably explain the difference in size of redds.

From all 77 streams collections were made of naturally spawned eggs or of alevins, mostly from the redds of brown trout, but in some places from redds of rainbow trout and of quinnat salmon. The total collections consist of samples from 711 redds which yielded 503,139 specimens. Of these, only 7.6 per cent. were dead. The total loss which occurs before fry emerge is in excess of 7.6 per cent., because much of the material might have suffered further loss before development was completed.

The average number of specimens obtained per redd was less than the average number of eggs produced by fish spawning in these waters. This was so mainly because each trout commonly makes more than one redd in a season.

If a series of samples at successive stages of development is taken from redds and examined, it is possible to estimate, with reasonable accuracy, the extent of the losses up to the time of hatching, and also to learn whether many alevins die. The bulk of the material collected from the spawning redds of trout, which is reported on in Bulletin 8, came from 64 streams comprising parts of 10 river systems. From nine of these systems, from which about 423,000 ova and alevins were collected, material was sufficient to warrant the estimation of losses. The estimated percentage losses of eggs in redds, up to the time of hatching, were, in the case of different systems, 3.20, 4.64, 5.50, 6.08, 6.85, 9.36, 11.38, 12.80, and 29.29. These give an average loss of approximately 10 per cent. This figure has been substantially influenced by the inclusion of data from one stream where losses were particularly heavy. The first eight figures give an average of 7.5 per cent.

The losses given do not include any resulting from dislodgment of specimens from redds, nor do they include losses of alevins. Of 141,935 alevins recovered, only 0.27 per cent. had died earlier. Dead alevins decompose very much more rapidly than eggs do, and those recovered may not include all which had died. However, from a consideration of the time it takes for dead alevins to reach an irrecoverable stage, and also of the duration of larval life, it seems certain that 0.27 per cent. represents more than a quarter of the total loss of alevins. Examinations of some redds from which fry were emerging, and of others immediately after emergence had finished, gave no ground for supposing that heavier losses occurred at such a time. It seems safe, therefore, to regard 1 per cent. as an outside figure for losses of larval fish in the average redd.

Data thus far indicate a loss of about 2.5 per cent. through eggs being retained in the fish, or failing to lodge in the redds, a further loss of about 10 per cent. before eggs hatch, and a loss of possibly another 1 per cent. before free-swimming fry emerge. These latter losses relate to eggs buried and not subsequently dislodged from redds. Although variation is shown from redd to redd, in general about 1 per cent. of this loss can be ascribed to eggs not being fertilized. The rest of the losses reflect, to a considerable extent, the presence in redds of excessive quantities of fine silty material.

When redds are constructed, fine material is disturbed and drifts away to leave a pocket of relatively clean shingle. Where the material used is dirtier than usual, fine matter drifts into the completed redd from the adjoining bed. This drift of fine matter may be aggravated during floods. Further, in congested spawning areas, as new redds are being constructed, fine materials may be dislodged on to older redds downstream from them.

A comparison of losses recorded in separate redds and in congested spawning areas showed losses to be heavier in the latter. Losses attributable to the causes just discussed are reflected in the figures given, for the lethal agencies in these cases do not dislodge the eggs which die.

DISLODGMENT BY LATER SPAWNERS

In addition to these recorded losses, death may result from actual dislodgment of eggs or alevins. Where this occurs, it has not been practicable to count specimens so lost. Data are available, however, which indicate the possible extent of the loss. The material considered in Bulletin 8 comprised samples from 524 redds. Of these, 193, or approximately 37 per cent., were separate ones where no question of dislodgment of contents arose. Each of the remaining 331, or 63 per cent., was in contact with one or more other redds. These were a mixture of cases of contiguous redds and of partially or wholly overlapping or overlapped redds.

Obviously, the contents of redds, the extremities of which just touched one another, and of redds built on others were not jeopardized. The only ones the contents of which were threatened with dislodgment were those on which others were constructed.

This number of redds may be taken at certainly not more and probably less than half of those in congested areas—that is to say, at not over 31 per cent. of the total redds. If the total contents of these redds had been dislodged, a very substantial addition would have to be made to the losses already recorded. But it is certain that dislodgment of the total contents of these redds did not take place, because subsequently in all cases it proved possible to collect samples, commonly of substantial size, from them. This was because—most often where overlapping occurred—the second redd would be commenced somewhat upstream from the point where the first began.

Further, eggs are not spread evenly through the redd, but are densely massed in one or more egg-pockets excavated to more than average depth. Usually the upstream end of a redd—that is, the portion most commonly overlapped—contains no egg-pocket.

The collections under discussion were made in a series of streams where superimposition, although observed in most cases, varied considerably in degree and the possibilities of loss likewise differed. As the streams represent most of the common types of trout water in the country, there is reason to believe that observations made on them have a fairly general application. If the material is considered as a whole, it is safe to say that some of the contents of a proportion of the redds, not exceeding 31 per cent. of the total, were jeopardized. Such losses as resulted were additional to those recorded.

DISLODGMENT BY FLOODS

Losses resulting from the precipitation of silt in redds are included in figures already given. It remains to consider whether additional losses are caused by floods washing out the contents of redds or by streams changing their courses and so leaving redds stranded. For floods to wash redds away, considerable scouring of the beds is necessary. All streams comprise reaches of contrasting stability. An overwhelming majority of trout and salmon select relatively stable areas of

stream-bed, where gravels are loosely cemented and consolidated. The marking of several series of redds has shown that, even in rivers generally considered to have loose beds, subject to frequent flood movement, redds withstand normal flood action because relatively stable sites are selected.

In most smaller streams studied, the beds were much more stable than in those in which redds were marked. In these smaller streams the possibilities of serious disturbance of redds seemed far less.

During winter floods of a severity unknown in at least the preceding 13 years, 27 per cent. of the salmon redds in a gorgy hill stream, Broken River, were washed away and a further 19 per cent. were left stranded. These losses took place during what is commonly termed in New Zealand an "Old Man Flood." In two other cases substantial changes in the courses of streams, with consequent damage to redds, followed the entrance of landslip debris into smaller streams. Such happenings are abnormal. Elsewhere abnormal flooding between spawning seasons is known in two cases to have washed away areas of gravel in which fish had spawned in many preceding years. Although these areas were not in use when these floods occurred, it is clear from time to time floods of sufficient severity to destroy redds must sometimes take place while eggs are in the redds.

It should, however, be noted against these few exceptional cases:—

(1) With normal flooding, the marking of redds gave negative results in streams selected as being most likely to show flood losses.

(2) Although it was a not infrequent happening in the course of five seasons' work to have to abandon operations temporarily because of floods, it was always possible, after subsidence of flood waters, to return and continue the excavation of series of redds, even the surface contours of which had not been substantially modified.

(3) In most cases the same portions of bed were used year after year in different streams. In many of them even the surface contours of many redds made the preceding season were still preserved at the beginning of the next.

(4) Inevitably over the years only the progeny of spawners most capable of selecting good sites and burying their eggs efficiently have survived; therefore, stocks could not be expected to be found spawning where flooding of usual severity always destroyed their redds. A number of stocks, including some in waters subject to regular heavy flooding, are known to have been maintained for many years solely by local reproduction.

On present evidence, floods seem chiefly significant, not in destroying redds, but in rendering unstable portions of bed which might otherwise be used by spawners. The selection of the spawning areas and the deep burial of the eggs ensure for most of the eggs a sufficient margin of safety from the direct action of normal floods. The margin is not, however, sufficiently great to safeguard all eggs from the direct effects of abnormal floods in all streams.

There are many streams not given to flooding and others where substantial increases in volume are not accompanied by much disturbance of the bed. In them the chances of any considerable number of redds suffering from direct flood action seem in some cases non-existent and in others remote. In other streams, and more especially those with flood-beds in which changes of course take place from time

to time, abnormal flooding, occurring in winter at infrequent intervals, may cause very substantial direct damage and resultant fluctuations in the density of stocks.

SUMMARY OF LOSSES

The losses discussed in this section are summarized in Table XVII. In addition, figures are given for losses on the assumption that the total contents of redds on which others were built were lost. It is known that the loss was considerably less and possibly greatly less. However, the practice adopted enables us to set out the possible limit of the loss.

TABLE XVII

NATURAL PROPAGATION

LOSSES IN THE PRODUCTION OF FREE-SWIMMING FRY

	Ova available in ripe fish: If 31 per cent. dislodged through superimposition.		If no ova dislodged.	
Total ova	100.0%		100.0%	
Loss of ova retained or not lodged (2.5%)	2.5		2.5	
	97.5		97.5	
Loss through superimposition (say, 31%)	31.0		.....	
	66.5		97.5	
Other losses in redds (as ova 10%; as alevins, say, 1%) 11% of balance	7.4		10.7	
Surviving fry	59.1	(59%)	86.8	(87%)
Total losses		(41%)		(13%)
		100%		100%

Losses arising from the precipitation of silt in redds through floods and through displacement of it on to other redds by late spawners are included in the figure of 13 per cent. Losses arising from dislodgment of eggs by late spawners are included in the figure of 41 per cent. Losses arising from the dislodgment of eggs during floods are not included. The figures do not, of course hold good for every stream; they represent the mean of results of spawning in many streams, some of which give much more and others much less satisfactory results than those indicated.

COMPARISON OF LOSSES

In considering the relative results of natural and artificial propagation, we must keep in mind that we are contrasting figures reached by treating as one each of two sets of data of heterogeneous origins. That is to say, we are concerned here with results of propagation at the typical New Zealand hatchery and in the typical stream. Therefore, general statements will relate to usual conditions to which undoubtedly exceptions occur.

We find that in natural reproduction the number of free-swimming fry produced is between 59 per cent. and 87 per cent., less any additional loss when floods

wash eggs out of redds. When artificial propagation is employed, the number of free-swimming fry produced lies between 46 per cent. and 67 per cent., less further exceptional losses which were ignored when reaching these figures. The position may be set out thus:—

	(1) Natural propagation.	(2) Artificial propagation.
Known losses	13 per cent.	33 per cent.
Plus (1) superimposition losses, or (2) wastage below traps, of possibly as much as	28 per cent.	21 per cent.
Plus, infrequent abnormal	flood losses	hatchery losses

It is clear that, if in each case losses resulting from superimposition and from abnormal causes are ignored, 20 per cent. more fry begin a free-swimming existence in streams under natural conditions than when man tries to improve on natural processes. The abnormal losses occurring in natural and in artificial propagation present identical features in that they occur irregularly but with much greater frequency in some localities than in others, and that in each case they may assume calamitous proportions. There are many streams in which major floods very rarely occur. There are hatcheries in which abnormal mortality has been avoided over long periods of years; yet a perusal of reports from many districts covering periods in some cases of up to 70 years shows that few have escaped occasional heavy loss and that sometimes, even in very recent years, there has been a succession of disastrous operational seasons.

It may be suggested that, because of superimposition of natural redds, the removal of the eggs of a portion of the fish results in the transference to hatcheries of eggs which would otherwise be wasted. This might be so if the erection of traps did not cause abnormal congestion of fish in restricted areas below traps—fish which would otherwise be permitted to disperse over a much greater area. In many New Zealand waters trapped in recent years, movement has been impeded, not only of the fish trapped, but of large numbers of fish which remained below the barriers until they were removed or which spawned below them and returned downstream. In one case, however, it would appear that most of the ova collected would otherwise have been wasted.

Earlier (Hobbs, 1940) it was shown that the quantity of eggs lodged and remaining in sample plots of spawning grounds of different rivers in which spawning was heavy did not usually exceed 1,200 per square yard. In the Kakanui River the mean effective deposition was about 800 per square yard of spawning ground used. In the Waihakahaka Stream (Hatchery Creek) at Turangi on the Tongariro River, the area suitable for spawning is much less than 1,200 square yards; yet up to 10,000,000 ova have been taken there in one season from rainbow trout which have entered this tributary to spawn. If these fish had been permitted to spawn, the mean deposition would have been in excess of 8,000 eggs per square yard, a quantity many times in excess of what appears to be the maximum effective lodgment in congested spawning ground. Under these exceptional conditions, a very great wastage through disturbance of earlier redds by later spawners could be expected if eggs were not collected.

It would appear from the facts available that **usually, but not invariably, in New Zealand artificial propagation of trout has been an inferior process to natural propagation as regards the percentage of fry produced in the two processes. From the broader aspect of fish culture, however, this would not matter if the transfer were effected of significant numbers of fish from areas where they were not required to areas where they were required, and if hatchery operations provided the most economical way of accomplishing such transfers.** The question of whether numbers handled are significant will be considered later. As regards most districts which draw supplies of ova from stocks subjected to angling and sell substantial proportions of the ova taken, it would seem inevitable that hatchery operations result in a reduction of useful local stocks.

Bodies which obtain eyed ova from outside their territories do not regard themselves as primarily concerned with the issue of the relative significance of natural and artificial propagation; yet obviously the quantities of fry released in such territories will be significant or not according as there is a large or small natural production of fry in such areas. A study of natural reproduction in the Waitaki, Grey, and Auckland districts, which relied on supplies of purchased ova, and a like study in the Southland, Otago, and North Canterbury districts, which have offered ova for sale, did not disclose any striking difference in the qualitative efficiency of natural reproduction in the areas controlled by bodies adopting these opposite policies.

Whether societies collect or purchase ova they effect transfers of fish. Evidence is needed as to whether or not the quantities shifted are great enough to effect substantial reductions where the eggs are collected, or to effect substantial increase of stocks where the resultant fry are released.

ARE HATCHERY FISH AS HARDY AS WILD FISH?

Where hatcheries have been operated in an attempt to improve on natural processes, there must have been a basic assumption that the hatchery products were at least as hardy as the natural products. There would have been little point in attempting to avoid losses, supposed to occur in the egg-stage under natural conditions, if any advantage gained was lost by the production of weakly fish unable to flourish in competition with wild fish. The question of the quality of the hatchery-produced fish cannot be satisfactorily answered by showing that they quickly learn to prey on live food or to react to moving shadows, nor is the question of how such fish fare in competition with others settled by reference to their known rapid growth and high rates of survival in virgin waters. There is very little recorded evidence of the relative growth-rates and mortalities of hatchery fish and wild fish sharing the same environment. Such evidence as there is does not encourage confidence in an equal ability of hatchery products to thrive in competition with wild fish.

White (1927), to whose early and valuable studies in Canada on losses of hatchery fry after release reference will later be made, contributed a fragment of evidence on this question. In a section of a stream, during a period in which only 36 per cent. of hatchery fry survived, 90 per cent. of a very small number of larger native fry survived. More recently Schuck (1943) in California showed

that a year after fingerlings of about three inches had been released in a stream only possibly as many as 6.3 per cent. were alive, whereas 24.1 per cent. of native-born fingerlings of the same age survived.

On the question of relative growth of hatchery fish and wild fish, Needham and Slater (1943) found that the growth of the latter in an equal period in the same water was, in length, about twice that of fish released at a length of 3.7 inches. The comparison is not an ideal one, as the hatchery fish were rainbow and most of the wild fish were brown trout, although the growth of two wild rainbow was in accord with that of the wild brown trout rather than that of the hatchery rainbow.

These few data, which suggest that the survival of wild fry and fingerlings, under approximately equal conditions, may be two and a half to four times as good and that growth also may be significantly better, necessitate extreme caution in assuming without further evidence that hatchery products possess an equal ability to thrive and to resist hazards.

THE SIGNIFICANCE OF QUANTITIES PRODUCED IN HATCHERIES

The Unconscious Propaganda of Numbers

The hatchery system in New Zealand is over 70 years old, which means that most anglers were born to it and have accepted it and have regarded it as essential to the well-being of their fisheries. Except in regard to losses in hatcheries where suppression of the truth still sometimes occurs, there is little evidence of conscious effort on anyone's part to mislead anglers. There has, however, been somewhat blind acceptance, frequent repetition, and application to waters of this country of the surmises of Armistead (1898), Day (1887), and others as to what the losses may be in English streams. Even as recently as January, 1941, a New Zealand fishing and shooting periodical stated in an article on fish culture that in a named hatchery "the average of mortality up to the time the eggs are ready for planting out is only about 5 per cent., whereas, under Nature's lavish system, a similar percentage is all that may survive." In point of fact, the staff at the hatchery in question admits, as published reports witness, an average loss before the eyed stage of about 20 per cent. Further, records published in 1940 and available to the same journal do not support the guess at the extent of natural loss in the streams from which this hatchery draws its supplies.

Recent European history shows that fiction oft-times repeated comes in a very short while to be regarded as fact. In intention the cases afford no parallel. However, as regards effect, the fiction regarding fish hatching has enjoyed the advantages of a start before its present adherents were born and of freedom from any suspicion of propaganda purpose. To a considerable extent, it is true that the fictions, already widely accepted when we encounter them in our impressionable youth, are accepted least critically by us and are later passed on to others with the conviction that attaches to sincerity.

When we come to consider hatchery output in relation to natural output of fish, we find that for up to 70 years much of the space in annual reports of controlling

The flood-breached rack in the Upukerora River—a Lake Te Anau (Southland, Sth. Is.) tributary where Atlantic salmon, brown trout and rainbow trout (in that sequence) spawn. The flooding was a disappointment to the egg collectors but possibly a benefit to local stocks, as, incidentally to the collection of a million or two eggs, the producers of several times that quantity were usually confined by the rack to a restricted area, instead of being able to disperse naturally to select the best spawning grounds in some miles of river. (Plate XI.)

The trap in the Selwyn River, Canterbury (Sth. Is.), where a census of the spawning stock of brown trout was attempted in 1941. Over 60,000,000 eggs were spawned there that year—that is three times the record annual hatcheries intake for all species. Earlier it had been thought that quantities of two to four million eggs, taken to the hatchery from the Selwyn, were sufficient to contribute materially to the maintenance of stocks in the North Canterbury district and in a number of other districts besides. The trap in the Selwyn used to interfere with the normal dispersal of many times the quantity of trout actually handled. (Plate XII.)

The little Waihakahaka Stream —a Tongariro River tributary (Nth. Is.) which has in some years yielded up to 10,000,000 eggs of rainbow trout for hatchery purposes—that is 50 per cent. of the peak intake for all species by all hatcheries. Here a substantial proportion of the eggs would otherwise have been wasted, as the spawning areas are much too limited in extent to accommodate, without disturbance of other eggs, all those which the fish would seek to deposit. (Plate XIII.)

Examining samples of eggs from superimposed spawning redds of brown trout below the ice in Lake Marymere, Canterbury (Sth. Is.). The very low lake level, evidenced by the exposed beach, may have increased the concentration of spawners by reducing available stony areas. (Plate XIV.)

Collecting a sample of eggs from a natural spawning redd of brown trout in the Horokiwi River, Wellington (Nth. Is.), as part of a series of studies of survival to different ages and of conditioning influences in this test stream. (Plate XV.)

bodies has been devoted to recording hatchery operations; no similar space is devoted to recording what hatched naturally. Newspaper publicity attends the collection of eggs and the liberation of fish, but does not record the natural hatch. Inevitably in these circumstances, public opinion must be biased on the question of the relative significance of the numbers of fry produced in hatcheries and the numbers produced naturally. It is not surprising that very commonly among anglers the maintenance of stocks has been credited to hatchery operations and that the natural hatch has been considered of almost negligible importance. Claims of success of hatchery operations in particular cases are considered in Appendix D, where a review of the evidence indicates that the claims cannot be sustained.

The numbers of eggs handled in hatcheries sound impressive and look impressive on paper until they are viewed in relation to the number of fish which produce them or the numbers of eggs not handled in hatcheries. Latterly, as attention has been directed to the contribution from natural sources, operations at some distributing stations have been reduced. Reference has been made earlier to the average hatchery handling of the years ended March, 1935, 1936, and 1937—a period which saw the peak of hatchery activity. The annual handling was approximately 20,000,000, comprising about 11,500,000 ova of brown trout, 7,750,000 ova of rainbow trout, and 750,000 salmon eggs. What do these numbers really mean?

First, it is reiterated that they do not represent gain to New Zealand waters as a whole. Only by so much as the number of fry produced exceeds the number which would have been produced naturally can they be regarded as gain—and there is reason to doubt whether, usually, natural processes are improved on and whether any general gain, as opposed to local gain, results.

Secondly, these 20,000,000 do not represent the whole of the eggs produced in the country. They are some of the eggs produced by some of the fish in some of the streams; some of the eggs, because many fish are partly spent when they reach the traps and, of the eggs they still contain, not all are taken by stripping; some of the fish, because some fish pass up the streams before traps are erected, others escape up during floods, and others go up after traps have been dismantled; some of the streams, because we saw earlier that only 19 streams, forming parts of 12 river systems, were trapped in a three-year period; yet the fish produced went into more than 364 streams and lakes comprising parts of about 100 river systems, and releases were not made into all waters containing trout.

The main sources of supply of brown-trout eggs for New Zealand hatcheries in the last 20 years have been portions of the Waiau system in Southland, the Water of Leith and Butels Creek in Otago, and the Selwyn River in Canterbury. Eggs of rainbow trout for acclimatization districts have come very largely from some small tributaries of Lakes Rotorua, Tarawera, and Taupo. A few facts are available regarding these sources of supplies which enable the quantities of eggs handled to be seen in proper perspective.

SOUTHLAND

Fish entering traps and netted below traps in tributaries of the Waiau system comprise a mixture of ripening, ripe, and partially spent fish. Ripe fish among 4,030 females captured in the Eglinton and Upukerora in 1935 yielded 5,648,000 eggs—a quantity exclusive of the proportion retained by each fish and exclusive of eggs

shed below the trap. The number taken from the average fish suitable for handling was 2,700. On the basis of data already referred to from the Selwyn River, this figure might be taken as representing 60 per cent. of total eggs produced by such fish. That is to say, the average production was probably about 4,000 ova. If all the fish handled had been ripe, and it had been possible to take all their eggs, the fish trapped should have yielded about 16,000,000 ova—that is, nearly three times as many as were collected.

In a composite year's operations, based on different years, when flooding has interfered less than usual with operations, reports show that the Mararoa, Wairaki, and a few much smaller Waiau tributaries have together yielded 4,400,000 eggs to the trappers. If this quantity bears the same relation as in the Eglinton to total eggs produced by fish trapped, the total usual production of fish handled in these other waters will be about 12,000,000. This suggests an annual production of 28,000,000 eggs by some of the fish in such Waiau tributaries as have been trapped. As even in the most favourable trapping years only a portion—and not necessarily a major portion—of the fish in any tributary is handled, 28,000,000 is only part of the production of eggs in such tributaries. It is a still smaller part of the production in the whole of the Waiau system, for great numbers of fish spawn in the main Waiau River, in the important Orawia sub-system, and in numerous smaller tributaries.

The Waiau is the largest of four major and several minor river systems in the Southland Acclimatization District. The greatest number of eggs ever collected in the district was nearly 7,000,000, taken from the Waiau system in 1925. Impressions of spawning areas and of stocks using them in waters of the Waiau system in Southland and in the Selwyn River in Canterbury are that the production of eggs of brown trout in the former is very much, and possibly many times, greater than in the Selwyn, where, as will be shown later, an attempt has been made to measure the production.

Waituna Lagoon and its tributaries comprise a small system draining into the sea on the south coast of Southland, a short distance east of Bluff Harbour. Waituna Creek, the largest tributary, is from 5 to 15 feet wide and follows a course of about 16 miles. In 1936 a trap was maintained in this creek from 25th April to 6th July. It is known that a few spawners had entered the stream before the trap was installed, that a small proportion of fish spawned before reaching the trap, and that fish were still running very strongly when the trap was removed. Of 1,904 trout trapped there, 1,177 were females. The latter totalled 7,367 lb. in weight. A sample of females of different sizes showed an egg production of 781 ova per average pound of their weight. On this basis the fish trapped are estimated to have produced 5,750,000 ova. This was probably a major part of the total production in the most important of several tributaries entering the lagoon.

Official records of the local acclimatization society show that the total liberations of brown trout made in Waituna Lagoon or its tributaries prior to 1936 amounted to only 15,000 fry, which were released in 1900. In Waituna Creek alone, the loss could rise as high as 74 per cent., and still the production of free-swimming fry would exceed the peak number of this species (1,506,000) ever released, as fry, from hatcheries in one year in the whole Southland district. In each of several years the eggs of brown trout collected in the Southland district exceeded in number those of this species collected in any other district at any time.

In 1935, which was a peak collecting year in the three main supply districts of Southland, Otago, and North Canterbury, the Southland hatchery intake of brown-trout eggs was approximately 40 per cent. of the New Zealand total. The number of eggs contained in the part of the Waituna run handled in 1936 was in excess of the quantity collected in Southland in 1935. The amount of spawning in Waituna Creek is probably considerably in excess of that which occurs in many other streams of similar size. Yet this is not known for certain, as no significance was attached to Waituna Creek as a spawning stream until its worth was demonstrated by trapping. Waituna Lagoon and its tributaries comprise an extremely small portion of the trout-bearing waters of the Southland district.

OTAGO

Supplies of ova in this district have been drawn from a number of waters, but to the greatest extent and most regularly in recent years from the Water of Leith, a small stream which runs a short course to enter Otago Harbour at Dunedin city, and also from Butels Creek, a very small stream which feeds a small lake in the upper portion of the Clutha drainage area. Prior to 1940, in addition to ova from wild fish, about 250,000 eggs a year were stripped from two or three hundred fish kept in ponds. The Leith eggs, amounting usually to 700,000 or 800,000 a year, are taken from a few hundred large trout which enter from the sea. In some years up to 550 of these adults have been removed to lakes. The release of hatchery fry in the Leith averaged over a number of years about 1.8 per cent. of the quantity of eggs removed. The relation of the number of eggs removed to the total production of all sea-run fish and stream fish in the Leith is not known. It is likely that in many years a majority of the fish entering from the sea are stripped. Ova taken in Butels Creek represent some, and probably a majority, of those produced by fish entering from the lake. In this stream in recent years, abstractions have ranged from about 1,500,000 to 3,000,000 eggs a year.

There are no data on the basis of which the total annual production of eggs of brown trout in the Otago Province can be estimated reliably. It is, however, certain that the waters which are trapped comprise an extremely small proportion of the trout-bearing waters of the province. Of the two small streams, the Leith is the more important angling stream because it flows through the capital of the province. Lakes Hayes and Butels Creek, which enters it, are in sparsely settled country.

The keeping of anglers' diaries was encouraged and arranged for through the initiative of Mr. H. G. Williams, of Dunedin, and the Otago Acclimatization Society. These diaries afford valuable data on the relative significance of the Leith and other waters. Numbers of anglers of mixed categories—men, women, and boys —who furnished returns ranged from 59 to 170 in different seasons. A total of 468 seasonal returns of individuals shows a total capture of 40,640 trout, with an average of 87 per angler per season. The average weight of seasonal captures by anglers was 91 lb. The total number of licence-holders in all categories in the Otago Acclimatization District over the four seasons 1932–3 to 1935–6 averaged 2,264. The diaries include a proportion of nil returns and records of very small captures.

Considered territorially, the returns show an excessive proportion from city anglers, whose poorer opportunities of reaching good water are reflected in lower average captures. The returns used do not take into account captures of visiting

anglers possessing licences issued in other territories. The average catch of 87 trout, multiplied by the number of licence-holders (2,264), indicated a total catch for the district of about 200,000 fish. The Leith and its tributaries are fished almost exclusively by some of the city's 960 anglers. As 11.5 per cent. of 200 city anglers who furnished returns had fished these waters, the estimated total number of anglers who fished them is 110. The returns show an average catch of 27 fish there. The estimated total seasonal yield to anglers of the Leith and its tributaries is therefore 27×110—that is, about 3,000 trout.

The Leith yielded about 80 per cent. of eggs of brown trout collected from wild stocks by the Otago Society in its own territory in the 14 winters preceding 1940. Some indication of the significance of the stock of this water in relation to others in the district is afforded by the fact that the estimated angling catch there, at about 3,000 fish a year, is only 1.5 per cent. of the estimated catch of about 200,000 trout for all the waters of the district. This statement exaggerates its significance if it is reasonable to infer that proportionately more of the stock of a small stream in a city will be taken by anglers than of larger streams more remote from a main centre of population.

No accurate estimate can be made of total numbers of eggs in potential spawners caught by anglers of the Otago district each season. It is, however, possible to learn whether or not the number of eggs destroyed in this manner is very great in relation to the numbers retained in local hatcheries for the needs of the district. Anglers' returns do not give weights of individual fish; only total weights of fish caught each season by each angler are available. An analysis of returns covering captures of 10,000 fish shows that there were 4,200 fish weighing about 2,800 lb. in returns, in which the average weight of fish is given at less than 1 lb; there were 5,800 fish, weighing about 7,700 lb., included in returns showing a higher average weight. The returns which showed average weights of less than 1 lb. must have included a number of fish which would have spawned during the winter following capture. Further, the bags with an average of 1 lb. and over must have included a proportion of fish which would not have ripened until subsequent winters.

An approximate idea of quantities of ripening eggs destroyed can be obtained by basing the estimate only on the fish in bags averaging 1 lb. or better. If, as has been shown, 10,000 trout included 7,700 lb. weight of fish in this category, then the estimated total catch of about 200,000 would have included about 154,000 lb. This, with numerical equality of sexes, would mean 77,000 lb. weight of females. At so low a production of 650 ova per lb., such fish would have produced 50,000,000 eggs at the end of the angling season—if they had not been killed. Whether the actual destruction of eggs is rather higher or lower than the figure indicated is not known. It is, however, clear that the number of eggs involved must be very great in relation to that collected for local hatchery uses. Further, the estimate is only of eggs destroyed in potential spawners, a number probably considerably lower in most New Zealand waters than those in fish which survive the hazards of the angling season and succeed in spawning.

A further approach to the question of the significance of numbers is made possible by data given by Williams (1945) in an interesting study of the depredations of the large black shag, or cormorant, in inland waters of the Otago Acclimatization District. The factual matter presented is significant. It comprises records

of the examination of 2,883 birds killed over a period of 23 years. Numbers killed in different months of different years are shown separately with numbers of trout they contained separated into groups of one inch. Estimates of size of fish, many of which were probably partially digested, are acceptable only as approximations. The data, as produced, show that approximately 75 per cent. of trout were between 6 in. and 11 in. in length. The mean number found per bird was 3.6 in eight non-nesting months and 6.5 in the four nesting months. The average for a balanced collection made throughout the year should thus be about 4.56. This suggests an annual consumption of 1,667 trout per shag. As it is improbable that each shag contained, at the time of death, all the fish it had consumed, or would have consumed during that day, the estimate is a conservative one. During seven weeks, when adults are feeding young, Williams found that each bird made four trips per day with food. This indicates an additional consumption of $42 \times 3 \times 6.5$ fish, bringing the annual consumption per bird to about 2,500 trout. On the basis of two birds per occupied nest, Williams estimated the inland shag population in the summers of 1926–7, 1936–7, and 1941–2 at 2,546, 856, and 3,506 birds respectively. Williams attributes the fall in numbers in the first 10 years to control by man, and the subsequent rise to absence of organized destruction during war years.

The numbers of trout destroyed in a year in the Otago district are estimated by the present writer, from the foregoing data, at not less than 6,360,000, 2,140,000, and 8,760,000 respectively, with the shag population at the three successive levels given. The estimated numbers of well-grown fish taken by shags each year greatly exceed the quantities of trout liberated, mainly as fry.

CANTERBURY

The Selwyn River—the main tributary of Lake Ellesmere, a large shallow coastal lake—is one of the oldest established collecting stations for eggs of brown trout in the country. The Selwyn has been trapped more regularly than any other water, and over the years has contributed a greater portion of the total intake of eggs of brown trout in New Zealand hatcheries than any other single stream has. Few records of actual quantities of eggs collected from the Selwyn in years prior to 1900 are available. The little that is recorded and consideration of the more usually noted numbers of fry produced suggest the improbability of a total of as high as 2,000,000 eggs having been reached last century. Incomplete records since then suggest yearly average quantities of about 200,000 for the ten years 1900–09, 800,000 for 1910-19, 1,200,000 for 1920–29, and 2,600,000 for 1930–39. It would appear that the total quantity of eggs stripped since trout were first established in Canterbury would not be more than 50,000,000. In the ten-year period preceding 1938 (when fears that the Selwyn stock was being depleted by stripping led to a temporary reversal of policy), ova collected from this river numbered about 26,000,000. Of these, about 3,000,000, or 11.5 per cent., went back mainly as fry into the Selwyn, Lake Ellesmere, and other tributaries of the lake. Losses, sales, and distribution in other waters accounted for the rest.

Progressively from 1938 the North Canterbury Society sought data on the relationship of the quantity of eggs usually handled to the total quantity produced in the river. The wisdom of tying down the field staff to the job of maintaining a trap at one point on one stream, at a time when spawning fish up many streams

were vulnerable to poaching, was seriously questioned. There was realization that salvaging of fish from drought-stricken areas afforded a less speculative means of improving on natural processes than hatchery propagation did. There was growing doubt as to whether hatchery operations were actually an improvement on Nature.

In 1941 the Society, in co-operation with the Fisheries Branch of the Marine Department, undertook a major field experiment. The obtaining of a count of the approximate total number of mature brown trout going up the Selwyn from its lower reaches and from Lake Ellesmere was attempted. Details of this undertaking are given in Appendix A. The number of mature fish which passed the trap site was 40,500, including 10,500 males. The production of ova by the 30,000 females that year is estimated at 61,500,000. This does not represent the whole of the production of eggs by trout in the Lake Ellesmere system. It is the number produced by many of the trout which entered the main tributary of this lake. Even the 30,000 females accounted for in 1941 were between nine and ten times as many as the maximum number ever stripped in a year in the Selwyn; such stripped fish always include a big proportion of partially spent ones. In satisfactory trapping years at the Selwyn, the number of eggs collected has been as much as a third of the total of eggs of brown trout required for all New Zealand hatcheries.

This figure enables us to see other numbers in better perspective. We find that in one year a proportion of the fish produced a number of eggs in excess of the total removed from the Selwyn for hatchery purposes during a long history of stripping there. The average annual number of fry or eyed eggs put out into all the waters of the Ellesmere system during 10 years preceding 1938 amounted to about 0.5 per cent. of the part accounted for of the total eggs produced in the Selwyn alone in 1941. Abstractions of eggs for hatchery uses, at the peak of 4,300,000 reached in the winter of 1933, amounted to only 6.1 per cent. of this number. Eggs of brown trout spawned in the Selwyn in 1941 numbered more than three times the total quantity of eggs of all species—brown trout, rainbow trout, quinnat and Atlantic salmon—put through all the hatcheries of the country in a year.

ROTORUA AND TAUPO

Rotorua and Taupo are the principal rainbow trout fisheries of the country. Their interest here lies in the fact that they have for long been the only important source of supply of eggs of rainbow trout for acclimatization societies in different parts of the country. This is not to say that eggs can be collected only in these areas. As rainbow trout are most abundant in these areas, large quantities of ova can be collected in them with greater ease than elsewhere. Different spring creeks feeding Lake Rotorua provided supplies regularly from 1902 until 1926. Since then, very large supplies have been drawn from the Waihakahaka Stream, a tributary of the Tongariro shortly above where it enters Lake Taupo. This small shallow spring creek, from which quantities of ova up to 10,000,000 have been removed in recent years, has an accessible course of less than a quarter of a mile and an average width of about 12 feet. As a collecting station, it contrasts very favourably with tributaries of high-country lakes containing rainbow in the South Island. It is remarkable that so small a stream can sometimes supply as much as one-half of the total quantity of eggs of all species handled at all collecting

stations in the country in a year. An idea of the size of the stream in relation to other tributaries of Lake Taupo can be gathered from the fact that the discharge of Taupo is about 5,000 cubic feet per second.

In the season of 1945–6, 13 anglers took 2,063 trout at Lake Taupo. If half these fish were females of an average weight of 4½ lb. and a productivity of 650 eggs per lb. of their weight, they would have contained about 3,000,000 eggs. This quantity would be nearly a third of the maximum ever taken in a year from that district for hatchery purposes and about a sixth of the maximum for eggs of all species handled in all the hatcheries of the country. The catch of those 13 anglers was only a fraction of the total catch of anglers at Taupo.

Of the two important rainbow fisheries, that of Lake Taupo, some 238 square miles in area and fed by the Tongariro and numerous other tributaries, is the more extensive. The connected waters of Lakes Rotorua and Rotoiti comprise only 46 square miles, but the relatively high proportion of shallow water they offer suggests that, area for area, they should be more productive than most inland waters of this country. Some indication of the extent of their tributaries is given by the recorded discharge of 500 cubic feet per second at the outlet of the lower lake—about a tenth of Taupo's outflow.

Rotorua rose quickly to prominence as an angling centre in the early years of this century. A local resident, the late Mr. Arthur Iles, who endeavoured to record all captures over the first few seasons made the following records available. Eventually the fishery became so important that adequate recording became more than a spare-time job, and Mr. Iles recommended the proper authorities to continue the work. Although this was not done, the records are valuable as far as they go.

Recorded captures in the season					1903–4	amounted to		13	tons	13	cwt.
„	„	„	„	„	1904–5	„	„	27	„	5	„
„	„	„	„	„	1905–6	„	„	38	„	18	„
„	„	„	„	„	1906–7	„	„	50	„		
„	„	„	„	„	1907–8	„	„	70	„		

Hamilton (1904) in a contemporaneous statement about the recorded catch of the first season says that another third could safely be added for unrecorded fish not brought in and weighed. Donne (1927), who was an officer of the Department which had charge of the fishery for many years, published the same figures for the first three seasons and says that to them 25 per cent. could be added for unrecorded captures. If the lower figure of a quarter is accepted as a rough measure of unrecorded captures, the total weight of fish taken in the first four seasons may be put at 162 tons. In the season 1907–8 the catch would have been 70 plus a quarter —say 87 tons. Records of 2,256 trout taken in that season show an average weight of 2.4 lb. Mr. Iles's records show a very steep rise as far as they go.

There is no reason to believe that 1907–8 represents a peak year. On the contrary, sales of licences continued to increase very rapidly until the outbreak of the Great War in 1914. Before that time it was found necessary to resort to netting the lakes and to excluding spawners from tributaries to help keep the stock within reasonable numbers. In eight years between 1910 and 1920 netting was carried out in Rotorua or Rotoiti and more than 250,000 trout, weighing about 216 tons, were destroyed before it was felt that angling intensity had increased sufficiently to control the stock.

A conservative estimate of average annual production from these waters may be obtained if one assumes that it amounted to the 87 tons reached as early as 1907–8, plus the average annual amount, an eighth of 216 tons, destroyed by nets. This gives a figure of 114 tons a year. The recorded numbers and weights of fish netted indicate an average weight of about 2¼ lb., although the average weight was higher before and after the period of netting. A rough approximation of total captures before the 1925–6 season is as follows:—

Recorded catches 1902–3 to 1906–7 plus ¼	= 162 tons
Estimated catch 1907–8 to 1924–5 18 seasons @ 114 tons	= 2052 tons
	2214 tons

This, at an average weight of 2¼ lb. a fish, would represent a total of about 2,200,000 trout. The average annual catch indicated was roughly 100,000 trout weighing about 100 tons. The combined area of the lakes is about 30,500 acres. An annual production of 100 tons per annum would work out at 7 lb. per acre. This figure, for lakes which support few other large fish, is so far from being exceptional for reputedly exceptionally productive water that the estimate on which it is based can safely be regarded as not excessive.

In the 23 years prior to the 1925–6 season there was destruction of unrecorded numbers of fish by poachers. Further, in an unrecorded number of years, there was destruction of eggs of part of the stock through a deliberate policy of excluding fish from spawning tributaries to reduce the amount of reproduction. Also in the same period 26,000,000 eggs were removed for hatchery uses by the bodies which at different periods had the administration of the fishery. This figure of 26,000,000 seems large, but its abstraction was spread over 23 years, an amount of about 1,100,000 a year; its size must be considered relatively to other quantities.

The catch, at 100 tons a year, would represent about 100,000 fish of 2¼ lb. If half were females the annual catch would include 112,500 lb. weight of females. The average size is such as to suggest that the great majority of the fish captured were ones which would otherwise have spawned at the end of the angling season. The number of smaller fish involved is not known. However, if the catch of potential spawners is put at 100,000 lb., and the production of eggs per lb. is taken at 650, a reasonably conservative estimate of potential production should result. This suggests a figure of 65,000,000 for eggs destroyed each year in fish which otherwise would have spawned at the end of the angling season. Eggs destroyed in fish captured over the period of 23 years may be estimated conservatively at 1,500,000,000.

It is improbable that the abstraction, over the same period, of 26,000,000 eggs for hatcheries elsewhere in the country could have made any significant difference to stocks of these lakes. The figure, roughly but probably conservatively estimated at 1,500,000,000 eggs, does not, of course, represent the actual production of eggs in these waters. It simply represents eggs which would have been spawned if fish had not been killed by anglers and nets. The fish killed were simply the excess which could be destroyed without causing any substantial diminution in the hatch resulting from the natural spawning of the stock which remained. I say "natural spawning" advisedly, because available records indicate that the total number of

fry of rainbow trout recorded as released in Lakes Rotorua and Rotoiti and tributaries in the whole thirty years' period preceding 1926 did not exceed 200,000, and all except 30,000 of them were released before 1910 and probably before 1905.

HATCHERY PRODUCTION AND ANGLERS' CATCHES

Releases of trout fry in different Otago waters each year are recorded in reports of the local acclimatization society. The annual yield of such waters to anglers has been estimated from 400 sufficiently particularized diaries. Data show that the yield of different waters is not proportional to the rate of stocking. In years immediately preceding the recording of captures, the Catlins River and tributaries received approximately the same proportion of the total fry released as the streams comprising the Pomahaka sub-system of the Clutha River—about 8 per cent. in each case. Yet the Catlins system yielded only about 3 per cent. of the total catch while the Pomahaka yield was about 12 times as great. Again, liberations in the Pomahaka were only about twice as heavy as in the Waikouaiti; yet the yield of the Pomahaka was about 30 times as great.

Estimates of total captures in different waters range from below 10 fish per 1,000 fry released in the Waitati and Evansdale up to about 400 fish per 1,000 fry in the Pomahaka. These data might at first suggest that, because of especially favourable conditions, proportionately more of the fry released survive in the Pomahaka than elsewhere, and that generally there is great variation in the numbers which reach legal size. However, the Pomahaka carries its quota of the natural enemies found also in the other streams. It may flood less severely than some other waters, but probably not less so than all. The Pomahaka is more remote from the chief residential centres of anglers than many waters where the return per 1,000 fry released is much lower. Thus it would not appear that because of heavier angling intensity, a greater proportion of fish released is taken in the Pomahaka than elsewhere. The angling intensity is heavy there, because there are more fish available there.

Consideration of cases from outside the Otago district—for instance, various streams at Inchbonnie in Westland and in the Waimarino district in the North Island, mentioned in earlier papers (Hobbs, 1937 and 1940)—shows that over long periods of years stocks were maintained solely by natural reproduction. These waters provide angling; some of them, angling of a high quality. Since certain streams, which carry stocks of the same natural enemies as are found in Otago, provide angling without regular releases being made from the hatcheries, it is unwarranted to assume that in Otago the yield of streams is determined by, or even substantially influenced by, the amount of regular artificial stocking. The big differences of yield in relation to stocking, shown by Otago waters, suggest chiefly that the additions comprise unknown fractions of the young stocks of such waters and that these additions are rarely significant in size alongside the natural hatch. It is only where waters are never stocked and possibilities of migration to them are excluded that it can be said, positively, that the stock is the product of natural reproduction. The hatchery products are scattered so widely that this type of evidence is not easily obtainable. On the other hand, it is only where possibilities of inward migration can be excluded, and it is known positively that no fish spawn, that the maintenance of a stock can be credited to man's efforts.

The few stocked waters known, where little or no successful spawning occurs, yet satisfactory fishing is offered, are lakes wholly, or almost wholly, devoid of long-finned eels. Such cases afford no evidence that a good angling stock can be maintained by artificial transfers of stock on the usual scale to the great majority of waters, where this predator abounds.

A series of mature fish examined in the Selwyn River during the spawning run of 1941 averaged nearly 3 lb., and produced about 715 eggs per lb. of their weight. This production is not high for brown trout. Nearly 500 of these females will produce 1,000,000 eggs, and a smaller number of males, possibly 125, will ensure their fertilization.

It was shown earlier that the average annual release of trout in New Zealand works out at about 158,000 per river-system, or at about 43,000 to a typical stream or lake, forming part of a river-system. Very largely these fish are released as fry. There are about 100 river-systems in New Zealand which are stocked fairly regularly. The number of fry a typical system receives from the hatcheries each year about equals the number of eggs produced by 78 Selwyn female trout. Twenty-one typical Selwyn fish produce as many eggs as the number of fry which go into a typical stream or lake.

Earlier we saw that the average number of fry released per angler per annum was about 1,300. Natural reproduction, it has been shown, usually gives a survival, as fry, of between 59 per cent. and 87 per cent. of the eggs produced. **Thus the number of fry released per angler each year would usually be much the same as that produced by the natural spawning of a pair of fish of 2 or 3 lb. alone.**

Although the number of fry released per angler is about the number produced by natural spawning of usual efficiency of a female of 2 or 3 lb. and a male, an addition of even this many fry is made only in districts where eggs are purchased from outside. An indication of what this scale of liberations means, even where it represents an addition to local stocks, is afforded by considering it in relation to a typical angler's seasonal catch. The records of anglers' seasonal "bags" from different parts of the country were considered earlier. They show an average kill of 189 lb. weight of trout of mixed sexes. If sexes were equally represented this would mean about 94 lb. weight of females. The weight of Selwyn females required to produce eggs of equal number to the fry released in a typical complete river-system is 78 $\times$ 3—that is 234 lb. A typical one of the stocked streams or lakes forming part of a river-system receives fry equal in number to the eggs produced by 21 females of like weight—that is to say, by 63 lb. weight of females. As we have seen, this is less than what one angler kills in a season and 234 lb. weight of females is less than what three anglers take.

As regards districts where supplies of ova are collected locally, references to production by other fish in them indicate that the quantities removed have little significance. Two diaries from the North Canterbury district are from anglers who fished almost exclusively in the lower Selwyn and off the mouth of the stream. One took 61 fish weighing 202 lb.; the other took 262 fish of unknown weight. Records made during the spawning run of 1941 showed that approximately three-quarters of the mature stock consisted of females. Thus the angler who took 61 fish probably killed about 45 females—a number sufficient to produce more than 90,000

eggs. The "bag" of the other who took 262 fish probably included about 196 females. These, if of usual size, could have produced 400,000 eggs. The larger catch, while certainly not a record for recent years at the Selwyn, is probably well above the average. The smaller catch is more typical.

THE RETURN TO THE ANGLER FROM KNOWN QUANTITIES OF FRY

Earlier it has been shown that high survivals to the free-swimming fry stage usually take place from eggs spawned naturally. Counts of numbers of redds in quite small streams reported by the writer in 1940 showed that the quantities of live eggs and larval fish present were often substantial. A recent study by Allen (1945) is of especial interest because it shows the survival in terms of yearlings and two-year-olds from a known quantity of fry, mostly the product of natural spawning.

The Horokiwi River, where the study was made, is a small stream in the Wellington district. The portion surveyed was about 7½ miles long, and much of it was 6 to 15 feet wide. Its proximity to Wellington city and good angling access permit it to be more heavily fished than most Wellington waters of like size. It probably comprises less than 1 per cent. of the available angling water in the Wellington Acclimatization District. Average annual releases of hatchery fry into it, at about 13,000, represented about 1 per cent. of the district hatchery output in the five years preceding 1941. In October, 1940, Allen found the number of fry in it to be 250,000. Such a quantity, in this very small stream, was approaching one-fifth of the annual hatchery output for the five years for the whole Wellington district. By the following October the 250,000 fry had dwindled to about 2,750 yearlings. Allen draws attention to a succession of winter floods in 1941 which may have reduced the survival. However, the previous year only 4,350 yearlings were produced. Thus the loss might be between 98 per cent. and 99 per cent.—say, 98.5 per cent. under usual conditions.

Observations on the survival from 4,350 yearlings showed that only 600 of them were present a year later. Thus the 1.5 per cent. surviving as yearlings were reduced by the loss of a further 86 per cent. to about 0.2 per cent. as two-year-olds. On this basis, 1,000,000 fry would produce 15,000 yearlings or 2,000 two-year-olds. On the same basis, the 1,300 fry per angler, which were released in peak years of hatchery activity, would usually have dwindled to about 2.5 fish, even as two-year-olds. Fish are usually in their third year and older when taken by anglers in most New Zealand waters. Even in heavily fished waters, only a proportion of those which reach legal size are taken by anglers. In the Horokiwi, where growth is rapid, Allen shows that the usual total angling catch was only 340 to 375 lb. weight of trout a season—a very small return in relation to the known high production of fry there. No special conditions are known to exist in the Horokiwi River which are likely to cause heavier losses than are usual in other streams.

Summary

The evidence as to quantities of eggs handled in hatcheries, in relation to total quantities produced naturally, clearly shows that the former quantity is of almost negligible significance in relation to the latter. This

is so, even although a major proportion of funds available for maintenance of stocks is already being expended on hatchery work. Evidence as to the relative efficiencies of artificial and natural propagation to the fry stage affords no indication that the former is usually substantially better than the latter. Further, it is improbable that, even if hatchery losses were much less than they usually are, any worthwhile margin over natural processes would be obtained. Only such a *margin* can represent gain to stocks as a whole. While, through the hatchery system, transfers of stock are effected, the numbers transferred are so small in relation to the natural hatch at most places of release that they cannot be expected to effect substantial local increases of stock. Conversely, the quantities of eggs collected comprise such fractional parts of the totals available in districts of collection that their removal is unlikely to effect more than a nominal reduction of stock in any such district.

Available evidence indicates that the possibilities of improving on natural processes will vary greatly according to the conditions where the eggs are collected and the procedure in taking them. This procedure may be very destructive, where it involves interference with the dispersal, over good spawning grounds, of many thousands of fish, of which only a small proportion are stripped, as has been the case in the Selwyn and Upukeroro Rivers. In the case of only one stream, the Hatchery Creek at Turangi, near Lake Taupo, it is strongly indicated that greater wastage would occur if a proportion of the eggs were not removed to the hatcheries.

There are limited possibilities of selecting, for exploitation of their eggs, stocks of trout where eggs regularly would suffer a very great loss. Where floods would regularly cause an exceptionally high rate of loss, it is improbable that runs of spawners sufficient in numbers and capable of being trapped will usually be found. An improvement on natural processes seems possible principally in the tributaries of such lakes as afford young fish better opportunity for survival than is usual in rivers. Especially is this so in tributaries of lakes devoid of eels, such as Lake Taupo, where sometimes a much greater proportion of the fish produced survive and mature than spawning grounds can accommodate. While such places appear to offer the best prospects of improving on natural propagation—and such eggs as must be taken could least harmfully be taken from them—this does not mean that eggs in sufficient quantity could be taken and hatched with a sufficient margin of gain to affect the general abundance of trout in the country.

The long-finned eel is very widely distributed in inland waters, is extremely abundant, and reaches very large sizes. In eel-less waters, such as Lake Taupo and the headwaters of the Waihou system and of the Wangaehu, stocks of trout reach densities quite abnormal by usual New Zealand standards, whether or not maintenance releases are made from hatcheries. These waters offer considerable facilities for natural reproduction, but not more so than many other waters which contain eels.

Gudopp's Lake at South Makirikiri, near Marton, and the Tomahawk Lagoons, adjacent to Dunedin, are either wholly lacking or extremely deficient in conditions suitable for the reproduction of trout. The experiences of anglers who, over many

seasons, have used stationary live baits in these waters without catching eels, and of others, who have set eel-baskets, indicate that long-finned eels, if present at all, are extremely rare. These lakes offer good trout-fishing. The stocks are maintained certainly very largely—probably wholly—by periodical releases of fish. Such cases do not afford evidence of a necessity for fish hatcheries, for a considerable number of the fish released into the Tomahawk Lagoons are naturally produced fish netted from nursery streams elsewhere. They do, however, show that small but useful fisheries can, under these specially favourable conditions, be maintained by the periodical transfer of fish.

It should not be inferred from the foregoing that it is desirable or necessary to transfer trout to all lakes which lack spawning tributaries and are not infested with eels. Lake Marymere is in the eastern foothills of the Southern Alps. Surface streams neither enter it nor drain it. Eels are entirely absent. Official records of the local acclimatization society report the release of only one consignment of brown-trout fry (10,000 in 1919) between 1892 and 1932. Godby (1919) found brown trout present in 1917, and I observed an abundant stock in 1932. Trout were then seen to spawn in gravels in marginal waters at points where no spring water entered. Examination of redds showed very heavy losses, which resulted in part from disturbance by later spawners of eggs buried by earlier spawners in the same restricted area of gravel. It seems likely that in Marymere abnormally heavy losses in redds are to some extent offset by the absence of long-finned eels—an absence which enhances the chance of survival of such fry as are produced.

Consideration of conditions in Gudopp's Lake, the Tomahawk Lagoons, and Lake Marymere indicates that generalizations as to the need for transferring trout, even to lakes devoid of tributaries suitable for spawning, are unwarranted.

Evidence presented here calls for a change of outlook regarding man's influence on the maintenance of stocks of trout. Before there can be any substantial advance in methods of management of stocks, it is necessary that some widely held assumptions should be dropped. These erroneous assumptions are:—

(1) That a significant proportion of the total eggs produced can be handled in hatcheries.

(2) That the losses incidental to their handling are so substantially less than would occur in Nature that a significant margin of gain results.

(3) That, by a wide dispersal of hatchery products, stocks are maintained, or at least significantly increased in most waters, and that, in almost all waters, releases on the present scale are necessary and beneficial.

So far man has introduced trout to a multiplicity of environments. From seed sown long ago stocks have developed well or poorly according, very largely, to the suitability of these environments. To-day, in most waters, differences in density of stocks reflect dissimilarities of the environments and also of the intensities of exploitation of their products.

GENERAL CONCLUSIONS

The evidence reviewed leads to the following general conclusions:—

(1) The major part of funds available for the maintenance and protection of stocks of trout in New Zealand has been devoted to collecting ova from wild stocks for hatcheries, and the regular stocking of most angling streams with fry.

(2) The losses resulting from interference with natural spawning runs and the artificial propagation of eggs obtained have usually been greater than would have occurred had fish been left to spawn naturally.

(3) The quantities of eggs taken have comprised so small a proportion of those available, even in the few waters where they have been collected, that it has proved possible to continue collecting over long periods of years, and sometimes on a greatly increasing scale, without exhausting these stocks.

(4) Fry, from quantities of eggs, which comprise fractions of those available at the few collecting stations cannot contribute significantly to the maintenance of stocks in the great number of waters into which they are released.

(5) Small but useful trout fisheries are sometimes maintained by regular releases of trout transferred, either directly from other waters or indirectly through hatcheries. This is known to be possible only under conditions especially favourable for survival, such as occur where there is a relative absence of predatory species of fish.

(6) The retention of fry in rearing ponds for release at a greater size could only be justified if the method resulted in the production of quantities of fish significant in relation to the numbers present where they were released and of equal quality to wild fish. Further, the life expectancy of such fish as survived the process would have to be increased by more than their increased cost of production. All three conditions are essential. The first cannot usually be fulfilled in New Zealand, and there is doubt as to whether the second and third conditions could be fulfilled.

(7) It is desirable to seek more beneficial ways of spending approximately 70 per cent. of the funds available for development and maintenance of stocks.

PART III

Recent Investigational Work on Fisheries Management in Other Countries

MUCH INVESTIGATIONAL WORK done in recent years in other countries bears directly on practical problems of fisheries management which are common also in New Zealand. Because of the general similarity of the life-histories of brown trout, rainbow trout, and brook trout, data relating to all three species are used here, although only two of them are abundant in this country.

The sockeye salmon studies from Cultus Lake are included because they constitute an outstanding contribution to knowledge of the relative efficiencies of natural and artificial propagation of a salmonoid fish. This salmon, equally with trout, is suitable for artificial propagation; it buries its eggs in the manner of trout.

COMPARISON OF RESULTS OF ARTIFICIAL AND NATURAL PROPAGATION OF SOCKEYE SALMON

Below the outlet of Cultus Lake, in British Columbia, Foerster (1936[1]) established a fence and traps which permitted him to check the size, composition, and yield of eggs of the spawning run of sockeye salmon which sought to enter the lake and its tributaries. At the same point the numbers and nature of young migrating seawards were later checked.

In three different years salmon containing 17,470,000, 250,000,000 and 24,900,000 eggs were permitted to enter the lake and its tributaries to spawn. The resultant product, in the form of seaward migrants which had mostly lived a year in the lake, was determined.

In three other years runs of spawning fish containing 8,770,000, 15,620,000, and 6,564,000 eggs were stripped, and the eggs were transferred to hatcheries from which the resulting unfed fry were released into the lake. The numbers of seaward migrants which these produced were ascertained.

In two more years eggs were stripped and, after being brought to the eyed stage, were planted in tributaries normally used by natural spawners.

The results of these studies, expressed as percentages of the original quantities of eggs which later developed into fish which migrated principally as yearlings, were:—

Natural propagation	1 to 3.0 per cent.
Artificial propagation with planting of eyed ova	1 to 4.7 per cent.
Artificial propagation with planting of fry	1 to 4.5 per cent.

Foerster interprets the results in these words:

"Due consideration of the ranges of variation in the percentages of efficiency for each of the three methods indicates that the differences which seem to exist between the methods are not significant. They do not

portray any distinct advantage for any one of the three methods tested."

In the years when fry were planted, separate determinations were made of losses in the hatchery and losses in the year of lake life following release. Later, Foerster (1938[2]) reported that about 65.4 per cent. of the heavy loss which takes place within a year of release of fry occurs in the first two and a half months. Following natural propagation, the losses in the redds of free-swimming fish could not, from the methods used, be determined separately.

LOSSES OF ARTIFICIALLY PROPAGATED TROUT AFTER LIBERATION

Mortality in Streams

MORTALITY OF TROUT FRY FOLLOWING RELEASE

White (1924, 1927, and 1929), in British Columbia, determined the losses among artificially propagated fry of brook trout in a period of three summer months following their release. His results are summarized in Table XVIII.

TABLE XVIII

Number of experiments.	Conditions.	Percentage mortality. Range.	Mean.
5	Released in stream containing older trout and other fishes	69.5 to 96.0	78.8
2	Released in stream containing older trout and no other fishes	63.9 to 78.6	71.2
2	Released in stream containing no older trout	49.6 to 54.4	52.0
1*	Released in stream containing wild fish—1,000 fry per unit area	.....	85.0
1	Released in stream containing wild fish—333 fry per unit area	.....	79.0
1	Released in stream containing wild fish—111 fry per unit area	.....	55.8

*Included in group of 5 experiments above.

These data show heavy losses under all conditions within a short period after the release of fry. Losses were substantially less in the absence of older trout. Where different quantities of fry were released into sections of stream of like size and containing like populations of older trout, losses were lowest where the concentration of fry was least. Wild yearlings and two-year-olds suffered a loss of 10 per cent. in the same period in sections of stream in which the loss of fry was about eight times as great.

In Newfoundland, Frost (1940) found a loss of 95 per cent. within three months when unfed fry of rainbow trout were released into a section of stream from which adult wild trout were excluded.

An extensive series of observations in California is reported by Needham and Slater (1944). Studies were made in controlled sections of a stream which contained wild brown trout in minimal numbers. The rate of stocking per unit was varied, and different quantities of older trout, naturally produced, were present in the different experiments detailed in Table XIX.

LAKE ALEXANDRINA—SOUTH CANTERBURY

One of the many high altitude South Island lakes in the back-country of Nelson, Canterbury, Otago and Southland, where brown or rainbow trout, usually of 3–6 lb. in weight, are fairly plentiful. Fish of this size and the pleasant surroundings prove a powerful attraction to anglers. Improved access and transport to these lake fisheries have tended to relieve angling pressure on streams in closely settled down-country areas.

These South Island lakes are more numerous and better distributed in relation to angling population than the North Island trout lakes.

In New Zealand lakes, brown and rainbow trout commonly attain a weight of about 3 lb. or more before maturing. In shore waters, readily accessible to anglers, tend usually to be dominated by mature trout and thus exploitation is directly against fish of the larger sizes. Although it is evident that young trout migrate from production areas to spawning tributaries down to lakes, usually in the first year of their life, there is little definite information in New Zealand of the whereabouts and feeding habits of immature trout in lakes. (Plate XVI.)

Ngongotaha River—principal spawning tributary of Lake Rotorua (Nth. Is.)—a lake in which trout stocks developed excessively with consequent deterioration in condition during the first 20 years of this century. Much of the lake is very shallow. With high summer temperatures, rainbow trout seek the deeper water or accumulate at the mouths of this and other cold-water tributaries. The spawning season is prolonged into the summer in the Rotorua tributaries. Indeed a few fish may be found spawning in any month of the year. In Ohau Channel, which connects Lakes Rotorua and Rotoiti, the spawning season is appreciably shorter. (Plate XVII.)

Waikato River—Auckland Province (Nth. Is.)—the Karapiro Dam, the second of several being constructed. Rainbow trout spawn in the main river and in a few short sections of small tributaries below falls. The dams flood and so reduce the extent of spawning grounds. Thus fewer trout will be produced for the greater area of water created. As a result of the earlier building of the Arapuni Dam, upstream, eels gained access to waters previously inaccessible to them. At Karapiro the State Hydro Electric Department co-operated fully with fisheries interests by clearing shrub growth from marginal shallows and by incorporating in the dam electrical devices to deter the upstream passage of eels at points where these fish might be expected to climb. (Plate XVIII.)

TABLE XIX

Species planted.	No. of lots.	Size of fish: Inches.	Duration of experiments: Days.	Percentage mortality: Range.	Mean.
Brown trout	21	1.25–1.56	108.5 (mean)	13.0 to 69.3	35.9
Rainbow trout	14	1.32–1.69	84 to 132	.....	57.3
Rainbow trout	28	2.88–3.72	123 (mean)	2.3 to 97.1	50.2

Substantial differences were apparent in mortality where the number and size of hatchery fry released per unit area were the same but the quantity of wild fish present varied. For instance, brown-trout fry showed a loss of only 13 per cent. in the presence of a few wild fish. Where the quantity of wild fish was, by weight, 25 times as great, the loss was 69.3 per cent. These losses took place in three or four summer months following planting. Observations on wild brown trout of three inches and over indicated an additional loss of 68 per cent. in the succeeding four winter months. The authors concluded that, **"Plantings of fingerlings are largely ineffectual in streams containing numerous wild trout, since competition and predation prevent any significant survival."**

MORTALITY OF FINGERLING TROUT FOLLOWING RELEASE

In the records which follow, releases of healthy marked trout were made under supervision into natural angling streams. Commonly access to such waters was restricted to one or more routes, where the catches of returning anglers could be examined. A check, in most cases by the employment of census clerks, was made of the fish of legal size taken by anglers. Less commonly, voluntary reports from anglers were obtained as a result of organized publicity campaigns. Observations were continued long enough, in most cases, to exclude the possibility of any substantial quantities of marked fish released remaining uncaptured in the waters. Further, the dispersal of fish from points of release was studied, and there seems little possibility that the general results were affected substantially by migration of fish to outside the observation areas. The outcome of these experiments is summarized in Table XX.

TABLE XX

Authority.	State.	Species.	No. of lots.	Size in inches.	Mean percentage return to anglers.
Chamberlain (1942)	Nth. Carolina	Rainbow	2	3	1.0
Randle and Cramer (1941)	California	Rainbow	–	Various	0.9
Surber (1940)	Virginia	Rainbow	1	4.2 to 6	2.2
Chamberlain (1942)	Nth. Carolina	Brook	2	3	0.8
Surber (1940)	Virginia	Brook	3	3.7 to 5.6	2.6
Chamberlain (1942)	Nth. Carolina	Brown	1	3	0.7

To become available to anglers, these trout had only to survive and grow to a length of 6, 7, or 8 inches. Within these limits, the minimum size varied for the different species in different States and sometimes in different years in the same State. It is evident that in all cases the return to the angler was very low, and from 97.4 to 99.3 per cent. of fish released were not accounted for.

SURVIVALS OF TROUT OF LEGAL SIZE

Conditions for the release of fish of legal size and for the collection of data on survival were the same as those described for the experiments with fingerlings. Because the periods through which fish had to survive before becoming available

to anglers differ, relevant data are presented separately in Table XXI for fish released in the autumn and in Table XXII for fish released during and shortly before the angling season.

TABLE XXI

AUTUMN RELEASES

Authority.	State.	Species.	No. of lots.	Size in inches.	Mean percentage return to anglers.
Chamberlain (1942)	Nth. Carolina	Rainbow	8	Usually 6 to 7½	9.2
Shetter and Hazzard (1942)	Michigan	Rainbow	4	Legal, i.e., 7	4.9
Williamson and Schneberger (1942)	Wisconsin	Rainbow	1	7 to 15	48.4
Chamberlain (1942)	Nth. Carolina	Brook	5	Usually 6 to 7½	6.4
Shetter and Hazzard (1942)	Michigan	Brook	3	Legal, i.e., 7	4.4
Williamson and Schneberger (1942)	Wisconsin	Brook	1	7 to 13	28.2
Smith (1940)	Michigan	Brook	2	7 to 9	0.5
Shetter and Hazzard (1942)	Michigan	Brown	3	Legal, i.e., 7	5.8
Chamberlain (1942)	Nth. Carolina	Brown	3	Usually 6 to 7½	14.3
				Average	13.7

In all cases the recaptures are greatly less than anglers would hope for, and very large percentages of the releases are unaccounted for. The variation in percentage of recaptures is very striking for waters which are all subjected to heavy fishing. These differences seem less likely to result from differences in fishing intensity than from other causes. Environments into which they were released were different. Neither the number of fish stocked per unit area nor the rate of stocking in relation to the numbers of wild fish present was uniform. White (1930) and Shetter and Hazzard (1940) show that, within limits, the smaller the number of fish released per unit area, the higher is the percentage surviving. White (1927, 1929) and Needham and Slater (1944) have shown that survival is conditioned by the quantities of older trout present. The most substantial recoveries of autumn-planted fish are shown from Wisconsin, where data available suggest that fish of a higher average size were released.

TABLE XXII

SPRING AND SUMMER RELEASES

Authority.	State.	Species.	No. of lots.	Mean percentage return to anglers.	Mean percentage for species.
Chamberlain (1942)	Nth. Carolina	Rainbow	6	58.8	
Shetter and Hazzard (1942)	Michigan	Rainbow	14	24.4	37.9
Williamson and Schneberger (1942)	Wisconsin	Rainbow	1	30.5	
Chamberlain (1942)	Nth. Carolina	Brook	9	44.5	
Hoover and Johnson (1937)	New Hampshire	Brook	1	70.0	
Williamson and Schneberger (1942)	Wisconsin	Brook	1	82.0	47.7
Smith (1940)	Michigan	Brook	5	16.8	
Shetter and Hazzard (1942)	Michigan	Brook	14	25.4	
Cobb (1933)	Connecticut	Brook and Brown		33.0	—
Chamberlain (1942)	Nth. Carolina	Brown	3	15.6	
Shetter and Hazzard (1942)	Michigan	Brown	7	12.0	13.8
			Average	37.5	

In Table XXII are recorded recaptures of trout which were of legal size when released. They were released mainly during the angling sason, but sometimes very shortly before it. Thus many fish were immediately available to anglers and others had to survive usually less than four weeks, but sometimes eight weeks, before

becoming available. The shorter the time which elapses between the release and the availability of fish to anglers, the less is the likelihood of their destruction by some hazard other than angling. Hoover and Johnson (1937) reported that 70 per cent. of brook trout released in the angling season were recaptured within three weeks, 45 per cent. by the end of the first week, and 60 per cent. by the end of the second. Eighty per cent. of the recaptures of brook and rainbow trout, reported by Williamson and Schneberger (1942), occurred in the first three weeks of the angling season. Shetter and Hazzard (1942) found that marked rainbow trout and brown trout contributed to the catch for at least eight weeks after release. Brook trout were caught out usually within four weeks. The majority of all planted fish taken was caught by the end of four weeks. The marked fish surviving from one season to the next constituted an insignificant percentage of the total catch. Smith (1940) found, where angling was comparatively light, the catch of marked fish was spread over the whole season, but that none of any survivors at the end of the first angling season lived to be taken in the next season.

For waters most of which are subjected to an angling intensity unusually high by New Zealand standards, the return to the anglers is low, even when fish are reared to legal size and released during or shortly before the angling season. Yet these survivals are greatly better than when legal fish are released in the autumn. With the exception of the aberrant case of rainbow reported from Wisconsin, survivals of legal-sized fish reported by different authors were for rainbow 5.0 to 6.4 times as great, for brook trout 2.9 to 7.0 times as great, and for brown trout 1.1 to 2.1 times as great when released in spring and summer as when they were released in autumn. Cobb (1933), who found no appreciable survival from autumn releases of brown and rainbow, reports a 33.0 per cent. return from summer releases. Nesbit and Kitson (1937), in Massachusetts, found that brown and rainbow trout of legal size released in spring gave five times the return obtained from releases in autumn.

The extremely rapid depletion of hatchery releases made during the angling season and the very low size-limits ruling might suggest that in heavily-fished streams of the United States few fish reach maturity and spawn. Such suggestion has not been sustained by several workers when the fish released from hatcheries have been marked and the percentage of unmarked wild fish has been learnt from examination of anglers' captures. Their results are:—

Naturally spawned trout in anglers' captures:

Randle and Cramer (1941)	97.9 per cent.
Surber (1940)	72.5 per cent.
Chamberlain (1942)	63.0 per cent.
Shetter and Hazzard (1942)	88.5 per cent.
Williamson and Schneberger (1942)	71.0 per cent.
Smith (1940)	61.4 per cent.

Similar results have been obtained in New Zealand. Shortly before the openings of the angling seasons 1940–1 and 1941–2, 1,421 brown trout, mostly of from 5 to 7 inches, were marked and released in three small tributaries of the Manawatu River—the Kahautarawa, Tiritea, and Scotts Creek. Marked fish comprised only 3 per cent. of 244 trout of from below legal size and up to 13 inches captured by anglers in these two seasons.

DISCUSSION

In so brief a treatment of the results of researches of so many workers it is not possible to do justice to their work nor to deal with individual interpretations of results of different experiments. There are difficulties in treating as a whole material so heterogeneous in character. The further condensation of results attempted is for anglers to whom the original works are not available. It is emphasized that losses vary greatly; the most that can be accomplished here is the presentation of a composite picture indicative of the loss under usual conditions. Because present evidence does not indicate any consistent difference in survival values of the three species under consideration, separate treatment will not be attempted.

Losses may be summarized as follows:—

Unfed fry—loss within 3 months of release	95.0 per cent.
1½-inch fingerlings—loss within 3½ months of release	63.0 per cent.
3–5-inch fingerlings not recaptured by anglers	98.0 per cent.
7-inch and larger fish—autumn releases not recaptured by anglers	86.0 per cent.
7-inch and larger fish—spring and summer releases not recaptured	62.5 per cent.

Unfed hatchery fry—usually of ¾ in. to 1 in. in length—were used only by Frost (1940) in a single experimental liberation. Loss at the rate of 95 per cent. in three months, found by Frost, is used in the estimation made below for the period not covered by other data—that is, one month. These fry had the advantage of release into an area from which older trout had first been removed. The loss for the next 3½ months is the mean of that found by White (1924, 1927, and 1929), where wild fish were present, and that of Needham and Slater (1944) where older trout were present only in minimal numbers. Losses of fry are likely to be underestimated because of partial reliance on data from areas where wild stocks had been modified. Survival from releases of fingerlings may be underestimated because the possibilities of migration and incomplete census returns were substantially, but not wholly, avoided.

The losses to the angler where trout become available, most commonly at 7 inches, are computed as follows (and shown in relation to southern hemisphere seasons) from a release of 1,000,000 unfed fry:—

Unfed fry, 1 month—October loss at rate of 95 per cent. for 3 months = 32 per cent. = 320,000 loss; 680,000 fish surviving.

1½-inch fingerlings, 3½ months to mid-February, loss = 63 per cent. = 428,400 loss; 251,600 fish surviving.

3 to 5-inch fingerlings, mid-February to next angling season, lost or not retaken = 98 per cent. = 246,600 loss; 5,000 fish surviving.

Loss by the time a length of 6 to 8 inches is attained = 99.5 per cent.

On this basis, 1,000 unfed hatchery trout fry, under conditions which seem most common in North America, could be expected to dwindle to 5 by the second summer after planting. A thousand fingerlings of 3 to 5 inches could be expected to provide anglers with 20 fish of legal size. A thousand fish of legal size released in autumn would usually provide anglers in subsequent seasons with 137 fish. Where fish of legal size are held for release during, or shortly before, the angling season, anglers can hope to recover, mostly within a very few weeks, about a third of the fish released. The other two-thirds are lost to the angler, and there

is nothing to suggest that any significant proportion of them survives to become useful in subsequent seasons or to contribute to the stock by spawning.

It is emphasized that the estimates made of survival from releases of fish of different sizes are only up to the time when fish become lawfully takable in the United States—sometimes 6 inches, sometimes 8 inches, but commonly 7 inches. They are not necessarily indicative of the full extent of loss under New Zealand conditions when the minimum size-limit ranges from 10 to 14 inches and is commonly 11 or 12 inches. From data assembled by Parrott (unpublished MS.), it is clear that, although some trout are taken here during their second year of life, much more usually they are in their third year when they first become available to anglers. Therefore, the losses considered are those to be expected during only the first of the two years which usually elapse before fish are large enough to be taken here. There is much to suggest that losses would be greater in that first year.

Are the losses during the first year greater or fewer in New Zealand? There is as yet no evidence available here suitable for comparison. The general conditions which give rise to part of the losses in North America are sufficiently described to warrant some comparisons with conditions here. Even in the absence of predation from birds and in the absence of predation and competition from larger trout or from fish of other species, a heavy and unexplained loss of trout fry takes place. (White, 1927, 1929, and Frost, 1940.)

Under usual natural conditions, additional loss takes place. Its extent is conditioned by the rate of stocking, from both natural and artificial sources, and by the quantity of older trout present and by the nature and quantities of fish of other species present. (Needham and Slater, 1944, and White, 1924, 1927, and 1929). Rarely in New Zealand are stocks fished so hard that the average size of fish taken is kept close to our much higher minimum size limits. Commonly here fish reach a much greater size.

In both countries the size of fry is similar, but here there would most commonly be many more large wild fish in relation to fry released than in the United States. Few of the North American authors other than White (1924) consider competition for food and predation, except by larger trout. This suggests that streams do not support other predatory species of the quantity and size found here. The female long-finned eel, a recognized competitor for food and predator, abounds in New Zealand trout streams, sometimes in quantities in excess of 2,000 lb. weight per mile of stream 15 to 30 ft. wide, and in some waters attains a mean weight of 13.2 lb. before migrating to sea.

In the United States there is evidence of a very heavy over-winter loss of fingerlings released in summer, "legals" released in autumn, and also of wild trout. As this loss is heavy when temperatures are very low and there is unlikely to be much competition for food or predation, it has been attributed to the severity of winter conditions. In New Zealand only exceptionally, and in restricted areas, does snow lie heavily on the ground, or does anchor ice form in streams in winter. Winter is shorter and conditions are less severe here than, for instance, in Michigan. Yet in a geologically "young" country such as New Zealand, flooding with substantial movement of materials comprising beds is probably more severe than in an older and larger land mass. Further, milder conditions here may make for a longer

growing season and consequently a longer period in which effects of competition and predation would be felt.

So far as available evidence of causes of losses goes, it discloses no reason for suggesting that losses in New Zealand should be any lower than they are elsewhere. Until they can be replaced by data arising from observations made under New Zealand conditions, the estimates of losses given here should be accepted as more reliable than surmises which have less factual basis.

Evidence of loss when fry are released from hatcheries in New Zealand is not available. However, evidence of loss of naturally-produced fry has recently been given here by Allen (1945). **His data from the Horokiwi Stream indicate a loss of 95 per cent. of the fry available in October by the following January and a reduction of 250,000 wild fry to 1 or 2 per cent. of that quantity within 12 months.** This survival of 1 or 2 per cent. may be compared with the earlier estimated survival of 0.5 per cent. in a like period from hatchery fry in the United States. The Horokiwi is a small and heavily-fished stream. Yet Allen shows that, **despite a production estimated at 250,000 fry in one year, the annual yield to anglers was usually only about 350 lb. of fish.**

Allen's data show a survival 12 months later of 14 per cent. of the natural yearlings present in October.

Fry or Fingerlings?

In an earlier section artificial and natural propagation were compared and it was shown that in terms of numbers of fry produced from quantities of eggs originally available, artificial propagation offered no advantage. In 1937 (Hobbs, 1937) I suggested that artificial propagation culminating in the liberation of unfed fry safeguarded the young through a period in which they were much less in need of protection than in the few months following their release. Two facts are self-evident: (1) The larger trout are when released, the greater is the proportion which may survive to be taken by the angler. (2) Larger fish cost more than small fish to produce; with a given sum of money, many small fish or fewer large fish can be produced. The question, then, is whether the difference between the survival value of large fish and small fish is more or less than the difference between the costs of production of fish of the two sizes. For instance, if large fish have five times the chance of surviving but cost five times as much to produce, it would matter little to a purchaser whether he spent his fixed sum on large fish, or purchased for the same sum five times as many fry. This is the problem in its simplest form, as it applies to an acclimatization society which purchases eyed ova from outside its territory with a view to hatching them and releasing the product, either as unfed fry or as fingerlings of 3 to 5 inches. On the basis of data considered earlier, the survival to the second summer in streams from unfed fry was 5 per 1,000 as against 20 per 1,000 for fingerlings. This allows for a loss of 75 per cent. of unfed fry in streams in the period (here taken at $4\frac{1}{2}$ months) required to bring fry to 3 to 5 inches in ponds. It gives the fingerlings a survival value of four times that of fry. However, it was stated earlier that losses of fry might have been slightly underestimated and loss of fingerlings slightly overestimated. Ample allowance should be made for possible error if fingerlings are given a survival value of from four to eight times that of fry. Then the question becomes one of whether 3- to

5-inch fingerlings can be produced at between four and eight times the cost of fry.

In Canada Mottley (1935[1]) found that when fry were being handled in large quantities they could be produced for about $1.75 per 1,000. The cost of 123,000 brown trout fingerlings of 3 inches was about $24.00 per 1,000. This amount includes the cost of the 170,000 fry required to give a survival of 123,000 fingerlings, the cost of food, wages and one-tenth of the cost of ponds required to hold the fish. These fingerlings, at three months, cost 13 or 14 times as much as fry. That is to say, it cost 13 or 14 times as much to produce fingerlings which at an outside estimation could not have had more than eight times the survival expectancy of fry. As Mottley's costing is for 3-inch fingerlings and the survival expectancy is taken from experiments with fish of 3 to 5 inches, it seems safe to assert that a better return to the angler would be obtained by buying fry than the much smaller number of fingerlings which could be produced for the same sum.

This conclusion is in keeping with that of Needham and Summer (1941) for brook trout of different sizes released into lakes at different seasons. Small marked fish of 2 inches mean length were released in autumn and larger fish of 5½ inches were released in spring. Although over five times as many of the large fish were taken by anglers, the cost *per fish creeled* was three times as great in the case of the larger fish.

Wales (1946) has shown with reference to fingerlings of 1.5 to 3 inches and yearlings of 6 to 7 inches, stocked in a Californian lake, that in the case of brown trout added costs of producing larger fish were roughly proportionate to the increase in survival value. With rainbow and brook trout in the same lake an advantage was gained because the survival value of the yearlings exceeded that of fingerlings by relatively more than the costs increased.

It is apparent that relative costs of production of fish of different sizes may vary from place to place and that the relative expectancies of life of fish of different sizes and of different species may vary according to conditions offering. Present evidence does not indicate that investment of money on large fingerlings or yearlings, rather than on production of fry, usually results in a greater benefit to the angler, although occasionally it may do so.

In this as in most other branches of fishery management there is need for strict costing of operations and for careful measurement of results if management is to be otherwise than highly speculative. No private citizen or trading corporation could afford to run a business with the disregard for costs and the extraordinary absence of information on results occurring from the investment of money which has characterized the so-called management of fisheries by State Departments and various organizations in this country and in others.

Fingerlings and Larger Fish in U.S.A.

Growing knowledge of the contribution to stocks from natural reproduction, dissatisfaction with results obtained in streams from release of fry in New Zealand and in the United States of America have led to a demand for more and bigger fish. In the United States there is no generally accepted policy in this matter. The few States where substantial proportions of the trout for release are held until they reach legal size have not contributed substantially to the investigations cited earlier, which aim at learning the value of releasing fish. On the other hand, in Michigan,

where six to eight million trout are planted each year, fish of 7 inches comprise only 3 per cent. of the total and (Shetter and Hazzard, 1942) they are released as an experimental measure. Only in New Hampshire (Chamberlain, 1942) is it claimed that a policy which includes release of fish of 6 to 8 inches is justifiable. This claim is made, however, in regard to a restricted area, for entry into which a special fee of $1.00 per day is charged and the streams in which are opened to angling for a much restricted period. There, too, in part, the aim is not to tax the carrying capacity of streams, but rather to increase the angling yield of streams by growing in ponds a supplementary crop of trout additional to the quantity it is thought that the natural food resources of streams will support. Even under these conditions, Chamberlain finds that natural reproduction contributes 63 per cent. of the fish taken by anglers.

The conditions under which large fingerlings and legal fish have been used in parts of the United States differ strikingly from conditions in New Zealand. (1) Larger fish have been tried principally in streams so heavily fished that such trout as are recaptured are taken within a few weeks of the beginning of the angling season. They are not required to first survive another year or more before becoming available to the anglers, as they would with the higher-size limits operating in New Zealand. (2) Commonly in heavily fished waters in the United States the average size of fish taken by anglers is little in excess of the usual size limits of 6, 7 or 8 inches; yet in such waters natural reproduction provides 61 to 98 per cent. of the trout taken by anglers. In New Zealand the average size of trout taken is commonly substantially in excess of the high-size limits of 10 to 14 inches, and the survival of more fish to propagate naturally is favoured. (3) The rearing of fish to legal size in ponds to provide fish in addition to what a stream can feed has yet to be justified as necessary and economically sound, and would prove greatly more costly where the legal size is as high as in New Zealand.

The Stocking of Lakes from Hatcheries

It is unusual to find river systems in New Zealand which are entirely devoid of conditions suitable for the reproduction of trout. Most rivers offer some areas suitable for reproduction, although the quality of such areas varies and the extent of them in relation to the total area of river water and to the food resources of the rivers may vary greatly.

Total absence of areas suitable for the reproduction of trout is a more common condition in lakes. Sometimes, when lakes have tributary streams, the area of spawning ground in the tributaries is better suited to the needs of those tributaries than to providing a stock also for the lakes into which the streams drain. Large lakes sometimes enjoy an advantage over streams because trout in them are less accessible to the angler and consequently more fish reach a reproductive size. However, the advantage may be more apparent than real where the concentration of spawners is in excess of what the spawning grounds can accommodate.

Few portions of river systems in New Zealand are inaccessible to predatory fishes, especially long-finned eels. Absence of eels is a more common condition in lakes.

Floods and droughts tend commonly to affect streams rather than lakes, and may therefore cause differential survivals. In the case of a stream, Allen (1945)

has shown that the estimated total weight of trout present fell by about 60 per cent. following winter flooding of extraordinary severity. For these and other reasons the problem of maintaining stocks in lakes warrants separate treatment.

Lakes themselves differ. The best, in addition to being suitable on physical and chemical grounds and having suitable conditions for the production of food, have sufficient spawning ground for a self-supporting stock of trout and an absence of other fishes, which might compete for food and prey upon the trout.

Such lakes, when they are first stocked, may be compared with a rearing pond, over which they offer certain advantages. The rearing pond should assure ample food and immunity from attack by larger predators. However, the necessary, but unnatural, congestion of fish in such ponds favours the spread of disease and parasites and also favours cannibalism among the fish. It is therefore probable that the loss of trout when released for the first time and widely dispersed in a lake, which lacks predatory species, may be less than in artificial ponds. Needham (1938) considers that in rearing ponds with satisfactory conditions, as regards abundance of natural food, suitable temperature for growth and protection from floods and from predators, survival rates of from 50 to 70 per cent. of young trout in three summer months may be considered satisfactory. Obviously if, when the young trout were released, they had to compete with other trout which had been bred there and were also likely to encounter older trout, not the same survival could be expected. Again, if eels or other predatory fish were also in the ponds, the survival might be still less.

Where lakes are devoid of tributaries and lack gravelly beds suitable for the reproduction of trout, angling can be provided most cheaply by the establishment of other game fishes, capable of reproducing and thriving there, or more expensively by periodical releases of trout. Because lakes, suitable in other respects, may contain an abundance or a paucity of predatory fish, the return to the angler from releases of trout will differ greatly under the different conditions.

SOCKEYE SALMON FRY IN A LAKE

The mortality of hatchery fry of sockeye salmon at Cultus Lake in British Columbia was studied by Foerster (1938[2]) as part of his comprehensive studies of the relative efficiencies of natural and artificial propagation. In three years the average survival from hatchery fry was 4.16 per cent. from the time of release until about a year later when they migrated seawards from the lake. The mortality in each year was over 94 per cent. He found that the percentage loss in numbers of fry liberated was heaviest during the first few months—approximately 65.4 per cent. in the first 2½ months—and that thereafter it decreased as the year advanced and the fish increased in size. When the numbers of predatory fishes (squaw fish, char, trout, and coho) in the lake were reduced, from 2½ to 4 times as many young sockeye salmon survived and migrated from the lake (Foerster, 1938[3]).

SURVIVAL OF TROUT UNDER DIFFERENT CONDITIONS

Studies of survival of trout planted in lakes have given varying results. In considering them it is necessary to distinguish between results obtained (1) from first releases into lakes containing neither predatory species nor competing wild young and predatory adults of the species planted, (2) from releases into waters containing young and old only of the species planted, and (3) from releases, where

the fish planted must meet competition and predation from other species, as well as from established populations of their own kind. Obviously the expectation of survival may be very different in these different cases. It may further vary greatly according to the number and size of fish released.

Experiments by Eschmeyer (1937) in Michigan cover cases of stocking in the presence and absence of predators and the effects of variation in the rate of stocking. Small lakes which contained many perch were stocked with trout, and yielded so few as to be valueless for angling. Lost Lake, of 4.6 acres, contained no trout or other competitive or predatory species when stocked with 200 fingerlings in 1927. In 1931 over 83 per cent. of these fish were taken by anglers. After the stocking of Lost Lake was increased to some hundreds of 5 to 8 months old trout per acre, the number caught represented only a very small percentage of the number planted. Shetter and Hazzard (1940) report recaptures of 50 to 70 per cent. of rainbow trout of legal size from different lakes the season following autumn releases. These lakes were mostly small—5 to 40 acres—and were stocked at the rate of 30 to 50 fish per acre. Some, and possibly all of them, contained no other predatory species, and usually heavy angling ensured that few fish survived to sizes greatly in excess of that of the fish released.

Needham and Summer (1941) report results of releases of brook trout in a lake of 5 acres which contained brook trout, rainbow trout, and a few large brown trout in addition to lake chubs which competed for food. Under these conditions 5,028 brook trout, 2 inches in length at the time of release, gave a return of 4.3 per cent. to anglers. Larger brook trout, averaging about $5\frac{1}{2}$ inches in length, gave a return of 25.6 per cent.

Smith (1946) reported on the return to anglers from releases of trout in eight Canadian lakes which already contained stocks. Over 60,000 fingerlings of 2 to 3 inches gave a total return of eight fish, 5,000 fingerlings of 4 to 5 inches provided anglers with 14 fish and of 2,845 trout of 6 inches or more in length, 14 were recaptured. In all, the 36 recaptured fish comprised only about 3 per cent. of those taken by anglers; the others thus taken were produced naturally. Where fish of 2 to 3 inches and of 6 inches or more in length were released in the same water, the percentage return from the larger fish (although of no angling significance) was 14 times as great as from the smaller fish.

Wales (1946) reports on survivals from releases of fish over a series of years in a high-country lake of 43 acres in California. The lake was stocked regularly with brown trout, rainbow trout, and brook trout. In addition it carried a small self-supporting stock of mackinaw. Fish were recaptured by anglers at mean sizes of about 10 inches for brown, 9 inches for rainbow, and 8 inches for brook trout. Survivals until recapture, after releases as fingerlings—commonly of between 1.5 and 3 inches in length—were 5.5 per cent. for brown, 3.5 per cent. for rainbow, and 1.9 per cent. for brook. Yearlings of 6 to 7 inches in length gave greatly better results—a return to the angler of 35 per cent. for brown trout, 39 per cent. for rainbow, and 40 per cent. for brook trout.

Long-term studies of survival to takable size from fry released in lakes are reported from Norway, Canada, and the United States. In a small lake in Norway, Dahl (1934) studied the relation of the harvest of trout netted for the market and the known quantities of fry released. Natural spawning took place in this water,

Its contribution to the catch was distinguished by a study of change in abundance of the year-classes following years in which hatchery fry were released. At the time of capture by gill nets, trout were usually of about 1.25 lb. and five-year-old fish predominated. The stock comprised many year-classes and included a few fish of up to 4½ lb. The author does not mention the presence of any other species of fish and it seems unlikely that many predatory fish would have been permitted in a small lake carefully farmed for profit. Over the whole period of 14 years a survival of 18 fish per 1,000 fry released is shown. As in some years poaching may have reduced the recorded catch, Dahl considers that selected years which show a return of 47 fish per 1,000 fry give a more reliable result. Thus the mortality probably lay between the limits of 95.3 per cent. and 98.2 per cent. Although systematic gill netting each year removed nearly all the large trout, natural reproduction still contributed about 50 per cent. of the annual yield.

Paul Lake in British Columbia is about 1,000 acres. Mottley (1939) has described the management of a rainbow trout fishery in this water. He says the lake was devoid of fish of any kind until 1909 when 5,000 fry of rainbow trout were put into it. The stock grew and multiplied to such an extent that an egg-collecting station was established in 1922 to provide stock for other waters. With improved access the lake was heavily fished. The stock became depleted in 1930 by heavy angling, by the collecting of eggs, and by the curtailment of natural reproduction through drought affecting a tributary stream for two successive years.

As a result of a policy instituted in 1931, of returning to the lake about 200,000 one-inch fry per annum, procured from eggs collected in a tributary, the lake was by 1935 and 1936 again yielding to anglers about the number of fish stated elsewhere (Mottley, 1933) to have been yielded in 1922. The yield in the last year reported was about 5 per cent. of the quantity released from the hatchery. The extent of natural production of fry may not have been considerable.

Mottley (1932) records the release in 1931 of 185,000 fry 1 inch long into the lake in July and the presence of 10,000 naturally-spawned advanced fry of 1.4 inches in a tributary in September. Data given earlier on losses in the first three months of free-swimming life must raise some doubts as to whether 10,000 advanced fry may not have been residual from a quantity of one-inch fry significant in relation to the number released. In another year (Mottley, 1933) small numbers of spawners were observed in another tributary and at the outlet of the lake. A survival of possibly up to 5 per cent., from the time fry of 1 inch are released, until anglers recapture them at an average weight of 1 lb., is indicated. Mottley (1935[2]) considers that yearlings are mainly responsible for the destruction of fry in this water.

The results of a programme of stocking, which included fish larger than fry, were recorded by Harkness (1940). Over a period of nine years 416,000 brook trout, half of 1 inch and the rest of 1½ to 2 inches, were released in a privately-owned lake of 11 acres. No other species of fish were present, and natural reproduction of brook trout was negligible. The catch over the years was approximately 5 per cent. of the number released. Mostly the fish were between 8 and 12 inches when recaptured.

The fishing in three other artificial ponds of a total area of 8 acres is owned by an angling club. Over a period of 11 years about 50,000 young trout, all brook

except 2,400 rainbow, were released, and anglers took about 15,000 fish of an average weight of 8 ounces and a maximum weight of 2½ lb. Apart from 20,000 fry released in the first year recorded, the average size of fish released in different years ranged from 4 to 8 inches. In the last seven years the total catch of 10,060 fish amounted to about 50 per cent. of the quantity released. Some natural propagation took place in tributaries. Other species, possibly competitive or predatory, were represented only by a few sculpins.

The gross annual yields per acre (that is, without allowance for weight of fish released) are 103 lb. for the 11-acre lake and 84 lb. for the second group. Favourable conditions were afforded through the substantial absence of competitive and predatory fishes and of very large trout. That is to say, the known factors which might have caused loss were largely limited to competition and predation within the species stocked, and exploitation by man kept the range of size of the species to within fairly moderate limits.

Except that in Norway, where the time that elapsed before recovery was much greater, there is a general similarity in the conditions and results obtained from releases of fry of the three different species of trout recorded by Dahl, Mottley, and Harkness. The survival in each case may have been as high as 5 per cent. The recapture of up to possibly 50 per cent. from large fingerlings, given by Harkness, may be compared with the return of over 83 per cent. from fingerlings reported by Eschmeyer. The known difference in conditions, which could have contributed to the higher survival in one case, is that the high survival was obtained from a release in water containing no trout and the lower from a release where a succession of year-classes was already present. Still lower survivals, of from 1.9 per cent. to 25.6 per cent. from fingerlings, were reported by Wales and by Needham and Summer, where three species of trout were present.

The data relating to lakes may be summarized thus:—

(1) Fry of sockeye salmon in Cultus Lake suffered a mortality of about 96 per cent. in the first year of life. When predatory fish in this lake were much reduced in numbers, the survival of salmon fry increased by from 2½ to 4 times.

(2) After the first stocking of a lake with trout had yielded an 83 per cent. return, the stocking rate was increased, but subsequent liberations yielded a very small return.

(3) The yield from releases of trout fry and small fingerlings has been studied in different lakes for brown, rainbow, and brook trout. In the absence of other predatory and competitive species, but in the presence of several year-classes of trout, the yield sometimes has been as high as 5 per cent. of the numbers planted.

(4) The yield from releases of well-grown fingerlings has varied from quantities ranging up to 25.6 per cent., where older trout of three species were present, to 50 per cent. where there were larger trout almost wholly of the same species, and to 83 per cent. in an extreme case, where the water contained neither older trout nor fish of other species.

(5) In general the data relating to survival of trout released in lakes are indicative of much higher survivals than are indicated by data, considered earlier, relating to survival in streams.

Discussion

The various overseas studies which have been reviewed relate to losses of trout released at different sizes and under different conditions. They supplement data from New Zealand on losses of eggs and of larval fish in natural spawning redds. There is also a close agreement between the results obtained overseas and results obtained in New Zealand by Allen (1945).

While there is evidence that under exceptionally favourable conditions appreciable returns are sometimes obtained from artificial stocking, the over-all picture negatives any suggestion that artificial stocking can be an economic way of maintaining stocks generally. **Revenue arises substantially from the licensing of exploitation of stocks which are produced naturally. It cannot be invested in artificial stocking with the expectation of accomplishing more than small increases in a few places where conditions favour survival exceptionally. This is so, irrespective of the size to which fish are grown before their release.** Larger fish cost much more to produce; their production is not without substantial loss; for a fixed sum far fewer large fish than small ones can be produced. It is necessary, therefore, to appreciate that very generally stocks are sparse or abundant according to the suitability of natural conditions. Accordingly, ways and means of spending limited funds to the best advantage must be carefully studied. Different possibilities of achieving a better balanced policy of management and a more economic return for expenditure are discussed in Part IV of this book.

PART IV

Future Management and Development of Fisheries

PAST EXPLOITATION AND STOCKING

THE LONG-CONTINUED increase in the demand for trout fishing in New Zealand has not been accompanied, in the last 40 years, by an equal growth of the stocks on which anglers depend. The demand has been met in part from exploitable excesses of existing fisheries, as in the Manawatu River, where increased exploitation proved possible without reduction of the reproductive capacity of the stock. In part it has been met by the better dispersal of angling effort, which with easier transportation, has been brought to bear increasingly on remote waters. The upper portion of the Waiau River System in Southland, the high-country lakes of Canterbury and the Rotorua and Taupo fisheries afford good instances of this. Again, in part, but only in a few localities, it has been aided by the making of artificial lakes such as Lake Mahinerangi in Otago. Further, and to an extent generally undetermined, it has been met by the sharing of the catch among an increasing number of anglers. Data from the Oreti River support this conclusion, but it is a matter often too self-evident to require demonstration in the case of small, readily accessible waters. Finally, and again to an extent not determinable, it may have been helped by a change in the angling requirement, as satisfaction from the skilled employment of light tackle has tended to replace the satisfaction of catching greater quantities of fish with heavier tackle and less skilled methods. The study of angling diaries suggests that a greater proportion of anglers now fish with light artificial fly tackle and that minnow and natural bait fishing are less favoured.

The acclimatization societies have attempted to meet the increasing demand for angling mainly in three ways: (1) By increased stocking from hatcheries. (2) As it became apparent that increased stocking was not giving results, fisheries research was started in the hope of acquiring knowledge as a basis for better programmes of management. (3) As it became apparent from the studies of Percival (1932) that angling intensity had an important influence on the size of fish and (Parrott, 1932, 1934[1, 2, 3, 4] and 1935) that stocks, which had often been considered to be old and stunted in growth, more commonly comprised well-grown immature fish, restrictive regulations increased. These regulations, principally of bag and size limits, aimed at compelling a better sharing of the fish amongst anglers and preventing the killing of too many immature fish. Because such regulations were not based on knowledge of what proportion of the stocks of the many different waters could be exploited, they were precautionary in intention.

It will be observed that the basic question of why increased stocking did not ensure increased fishing had remained unanswered. Apart altogether from any question of whether artificial propagation is an improvement on natural propagation,

there are fundamental biological reasons why increased stocking gives increasingly poor results. This can be established in several ways. The work of White (1930), Shetter and Hazzard (1940), and Needham and Slater (1944) showed that, after stocking, the greater the density of stock was per unit area, the poorer was the percentage of survival. Again Nicholson (1937) has shown that predation becomes increasingly effective as the prey species increases because, with an increased density of stock, the probability of encounter of predator and prey increases.

A further effect of change of density of a stock was shown by the writer (Hobbs, 1940). Spawning areas are limited in extent. As a population develops beyond the point where additional spawning ground is available, destruction of eggs at an increasing rate takes place because later spawners disturb older redds in depositing their own eggs. Pritchard (1939), in a study of the pink salmon, shows how survival may be conditioned by density of population. Deposition of eggs in a spawning area and the percentage of resultant migrants which left it in different years were stated thus:—8.5 million eggs gave a survival, as migratory fish, of 24.0 per cent.; 13.3 millions, 16.7 per cent.; 50.9 millions, 10.6 per cent.; 53.3 millions, 6.9 per cent.; and 139.0 millions, 9.1 per cent.

The basic physical and chemical limitations of environments, which compel populations to control their densities through competition, bring into play a system of natural regulation. This system so operates that, on the one hand, it opposes with increasing force attempts of a population to develop beyond a certain level. On the other hand, it permits survival at an increasing rate when, through exploitation or natural causes, the density of a population drops. The rule that a stock may be considered as the product of a like number of eggs to that which it produces is sound only as regards a wild population at its mean density. When, through exploitation, a stock is brought below its mean level, the expectation of survival of the individual rises, and a pair of fish produces more than one pair. Foerster (1936[2]) has shown, in the case of an exploited stock of sockeye salmon, that in some years the spawning of the average pair resulted in the production of as many as five or six pairs of fish.

Elsewhere (Hobbs, 1936) attention was drawn to a fundamental weakness of a system of stocking under which the rate of artificial stocking increases only proportionately to the increase of angling effort. Where natural spawning occurs and artificial stocking also takes place, stocking must be increased more than proportionately to the angling effort, if the earlier standard of fishing is to be maintained. Allen (1945) shows that the number of fry present in the Horokiwi River in October, 1940, was about 250,000. This small stream in that year was stocked with 10,000 hatchery fry, the same quantity as it received in each of the previous two years. Thus a twenty-fifth of the fry may have come from the hatchery and the rest from natural spawning. If licence sales and angling effort were doubled and the artificial stocking were doubled, there would be 260,000 fry, as against 250,000 when there were half as many anglers. **To provide double the amount of angling, the artificial stocking rate would need to be not doubled, but increased in this case by over 25 times.** That is to say, at least 500,000 fry would be needed; of these, not 20,000, but 260,000 would have to come from the hatchery. Even then it is questionable whether 260,000 hatchery fry would

accomplish the purpose, for with the increase of stock the mortality rate could be expected to rise.

In the light of the foregoing it is clear that a system of fisheries maintenance or development which depends mainly on artificial stocking cannot hope to achieve much. The question then arises of how funds and resources can best be used. This is not a question which is near being finally answered. Yet knowledge has grown sufficiently in recent years to show conclusively that the bulk of the funds available has been spent to little purpose and also sufficiently to indicate the general character of a more promising future policy. Any future policy should be regarded as provisional and subject to periodic re-examination and modification as knowledge arises from continuing research.

Because the present factual justification for different possibilities of fisheries improvement varies greatly, an attempt will be made to indicate in broad terms to what extent different measures are warranted by available evidence. Such an attempt should be regarded simply as a progress assessment which must from time to time be modified, as with the growth of knowledge management is able to operate in a progressively less speculative fashion.

DEVELOPMENT OF NEW FISHERIES

Present knowledge does not indicate the likelihood of there being a second great development of inland sport fisheries comparable with that which followed the introduction of brown and of rainbow trout. The establishment of salmon of different species has been attempted in a great number of waters in the North and South Islands. Two species provide angling in a limited number of rivers entering the east and south coasts of the South Island. Possibilities of establishing further species of the Pacific series seem substantially limited to waters where they would have to compete with quinnat salmon and brown trout. Past experience raises no hopes of establishing Atlantic salmon as a sea-running fish in New Zealand.

The superimposing, as it were, of a second fishery on an established one is a hazardous venture, if the two species come into competition for some essential environmental needs. The establishment of rainbow trout in Lakes Rotorua and Taupo, after brown trout had become established, appeared to lead to a reduction of the earlier stocks to relatively insignificant proportions. Fontinalis throve in the Tahuna-atara Stream until rainbow were released. Fontinalis were extensively propagated before 1900 for release in many waters where brown trout were already established, and almost everywhere failed (Thomson, 1922).

Although the brown trout affords excellent angling in many lakes of the South Island, there are certain lakes in which this species proves too difficult for most anglers to catch. In Lakes Te Anau and Coleridge, the introduction of rainbow trout, after brown trout were well established, proved useful as the brown trout were extremely difficult to capture and the rainbow were relatively easy. In Lakes Rotoiti and Rotorua in Nelson rainbow showed up for only a short time after release in water where brown trout had long been present. Unsuccessful attempts have been made to establish rainbow trout in waters where brown trout are already established in very many streams in both the South Island and the southern portion of the North Island.

Both experience and common sense suggest it as a sound rule of fisheries

management to leave well alone and not to add to the complications of management by trying to establish a second or third competitive species where a species already present provides satisfactory angling.

In addition to waters where good or moderate stocks of trout are found and provide satisfactory angling, there are many others in which trout have failed to become reasonably abundant, despite many attempts at stocking. Such waters include a number of flood-swept, loose-boulder-bedded streams, deficient in food and in conditions favourable for the reproduction of trout and salmon. Streams which suffer these deficiencies to substantial but somewhat varying degrees include the Waiau in North Canterbury, the Awatere in Marlborough, the glacial Waiho in Westland, the Otaki in Wellington, the Hangatahua in Taranaki, and the Kaueranga in the Auckland province. These waters are not all troutless, but, at the best, stocks build from a very low level to a slightly higher but still poor level if the rivers escape usual heavy floods for several successive years. It is unlikely that any substantial return can ever be obtained from funds spent on stocking waters which have the fundamental deficiencies of food and of ground suitable for reproduction.

The extent of the food resources of a stream and the extent of the spawning ground it offers for trout and salmon are not things which bear a fixed relation from stream to stream. It was shown by the writer (1940) that very generally stocks have developed to a point where spawning grounds are used to somewhere about their maximum useful capacity.

While it is true that in certain loose-bedded shingle streams there are somewhat balanced deficiencies of food and spawning grounds, there are many waters where food is present in quantities greatly in excess of the needs of trout produced in available spawning areas. The most extreme instances of this are afforded by such lakes as are entirely lacking in types of bed suitable for the reproduction of trout. Many small lakes of this character are found in the western coastal belt of the North Island. There are, especially in the northern parts of the North Island, river systems of slight gradient with gravel reaches only in the headwaters. Such reaches are too restricted in area to provide for the reproduction of sufficient trout to populate the lower waters.

Again, there are on both coasts of the North Island rivers flowing through soft sedimentary rocks which do not produce good gravels in which trout will spawn successfully. In many of these waters, abortive attempts have been made in the past to establish self-supporting stocks of trout. In most of them the survival from stocked fish has been insufficient to encourage regular artificial stocking. It is this series of waters which offers the main hope of developing new self-supporting fisheries. This will ultimately call for the introduction of species able to reproduce successfully under the conditions offering and able to develop in waters which contain an abundance of eels.

However, before the introduction of such fish as the North American fresh-water basses or possibly one or more of the Australian perches can be seriously considered, fairly precise knowledge will be needed as to the environmental requirements of such fishes and of the environments offering in this country. It is highly desirable that future introductions of fish should be rigorously controlled and should be made with proper foreknowledge and only for the development

of fisheries where experience has shown that trout are not satisfactory. The history of acclimatization of salmonid fishes as given by Thomson (1922) suggests that abortive attempts to establish different species greatly outnumbered the few successes. There is also evidence of great waste in attempts to establish additional salmonid species in waters already offering good angling. A species which is established and is later found to be unsuitable may never be brought under control. The introduction of additional species is not a matter to be undertaken lightly. There is, however, reason to hope that. with proper care, useful, and possibly extensive additional fisheries may later be developed, especially in portions of the North Island. This is most likely to be accomplished without waste of money if strict attention is paid to the following points:—

(1) Releases of additional species should not be made in waters where self-supporting stocks of suitable game fish are present and are making reasonably efficient use of available food resources.

(2) If more than one species is needed to ensure reasonable use of food resources, the second species introduced should not be one competitive with the first for spawning ground, cover, or whatever else has stopped the development of the first species at too low a density of population.

(3) Any additional species established should be attractive (a) as a game fish and (b) a table fish and (c) should be capable of reproducing naturally and (d) under wise regulations capable of providing a high-continuing yield to anglers, and (e) should be capable of developing naturally to a point where it makes efficient use of available food resources.

MANAGEMENT OF EXISTING FISHERIES

The Use of Hatcheries

Earlier, it was shown that hatcheries failed to aid significantly the maintenance of natural stocks for three basic reasons.

(1) The losses in artificial propagation are usually of much the same order as those which occur in natural propagation.

(2) Even when most of the funds available are spent on artificial propagation, the quantities of fish made available for transfer through the hatchery system are too small to contribute significantly to the stocks of most waters or to reduce significantly the stocks where the eggs are collected.

(3) A rate of artificial stocking which increases only proportionately to the increasing demand for angling cannot satisfy an angling demand which hitherto has been met mainly by naturally produced stock. This is so because only the lesser of the two sources of supply is increased.

Hatcheries served a useful purpose in the acclimatization phase of fisheries work. At some later time in some parts of New Zealand they may again become useful if the introduction of further species is attempted. Their value in aiding the maintenance of stocks of established species in most waters of New Zealand is very slight. Trout and salmon hatcheries should no longer be regarded in New Zealand as a means of increasing significantly the total stocks; rather, they should be regarded as facilities, sometimes useful, to help in transferring stock to a limited number of waters. Such waters are, so far as is known, only certain

of the lakes, where, in the absence of good spawning grounds, transfers are necessary, and where, often because of dearth of predators or other favourable environmental conditions, such as lack of flooding, the survival value of the small quantities which are released is enhanced.

In future, such transfers should be made only on the basis of definite knowledge that they are both necessary and beneficial, instead of on the assumption that they are everywhere necessary. They should be made only where no other readily available and satisfactory species could be expected to develop into a useful self-supporting stock. They should be made through the hatchery only where suitable fish cannot be salvaged in sufficient quantity from drought areas and where no naturally produced excesses, over the needs of parent streams, can be netted out and transferred.

The great scaling-down of hatchery operations now recommended calls for a consideration of what hatchery plant will be required in future. With good motor transportation, improved roads, and smaller quantities of fish, a very few small regional hatcheries should be able to meet all reasonable requirements. Probably a sum considerably in excess of half the gross annual revenue from angling licences —or staff services of that value—should become available for employment in fisheries maintenance and developmental work of other kinds.

Environment Improvement — Chemical

POLLUTION

The better control of pollution offers in many rivers definite possibilities of safeguarding and improving fisheries. Its efficient control calls for good legislation, impartial administration, and the availability of technical information to those charged with the duty of law enforcement. The present control is inadequate for several remedial causes. These are:—

(1) The legislation is out of date because the list of prohibited pollutants has not been altered to conform with needs arising from development of new types of industry. Prohibited substances include sawdust, sheep-dip, and flaxmill refuse, and relate to a more primitive period of industrialization. The subsequent development of meat and dairy produce export industries and the present wide use of oil and tar call to-day for equally express prohibitions of the discharge into streams of inadequately filtered matter of other kinds. It is inequitable that the burden of proof should be different in the case of equally injurious pollutants.

(2) The legislation is out of date because it was framed in a period when the amount of leisure was less and before the motor-car facilitated travelling to streams. It was passed generally in the interests only of fish. Locally, and only from a health angle, legislation provides for the protection of the interests of the public. The public should have a right, safeguarded by legislation, to the enjoyment of clean streams, and the standard of cleanliness should not be simply that the water is not toxic to introduced fishes. Other legislation is restricted in purpose to the protection of public health in boroughs and town districts only. It does not aim at the preservation of the amenities in country areas nor provide adequately for their preservation in towns or boroughs.

(3) The administration is partial, inherently, because the onus of proof is

different in the case of different equally noxious substances. It is often partial because the financial strengths of local bodies responsible for the enforcement differ; only some can risk losing cases against powerful interests. It is sometimes partial because of the conflicting interests of those responsible for law enforcement. More uniform administration should be possible if the onus of prosecuting was reserved by the Government, which should bear the expenses of proceedings.

(4) Law enforcement officers are appointed by the Crown under the provisions of the Fisheries Act, 1908, but their local activities are controlled by acclimatization societies. Such officers rarely have the technical knowledge necessary to investigate suspected pollution, except in the case of proscribed substances. Their position would be much strengthened by bringing the list of proscribed substances up to date and by the provision, when necessary, of technical assistance through a central authority.

A progressive deterioration in the state of streams in certain parts of New Zealand has long continued. It should be remedied in the interests of the public and in the interests of indigenous fauna as well as of introduced fishes.

FERTILIZATION OF WATERS

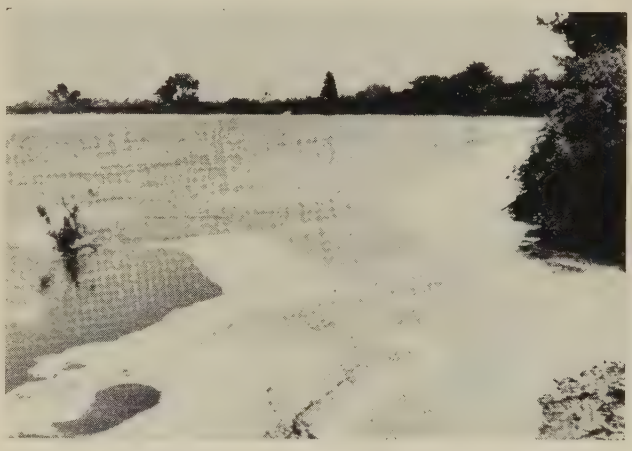
In New Zealand, where most anglers have some familiarity with the top-dressing of farm lands or of home gardens, reports of fertilization of waters in other countries have stimulated interest in the possibilities of improving the carrying capacities of lakes and streams in this manner.

It is emphasized that there has been no recent discovery of improved methods which now make more practicable the fertilization of natural trout waters. What has happened is that methods of improving small artificial ponds by the addition of chemical fertilizers, which have developed over a period of more than 20 years, and, by the use of organic manures, known over a much greater period, have recently been more widely publicized. As yet, appreciable results seem to be obtainable usually only in shallow artificial ponds which are drained annually for removal of crops and the control of stocks, which commonly in Europe are of carp, and in North America are of bluegill bream and bass.

The basic nutrient substances present in lakes vary in quantity largely according to the nature of the surrounding country from which drainage water enters. Usually drainage through fertile lowland flats will be richer in nutrient matter than drainage off barren mountain ranges. The concentration will commonly be greater where the volume of a lake is controlled by evaporation than where evaporation is slight and there is a large outlet stream. Nutrient matter brought in by streams will be better retained by some types of lake-bed than by other types, and will be more readily converted into crops in hard water than in soft water. The proportions of different basic nutrients vary much in different natural waters, with the result that different deficiencies and excesses are found. In the case of many streams, it is probable that with the development and top-dressing of farm lands there has been an enriching of natural waterways by drainage into them of both inorganic and organic compounds.

Opposing the enrichment of inland waters are the constant draining to the sea of compounds in solution and of suspended matter, the permanent absorption into mud of nutrient salts, the removal of crops of fish by anglers, and the migration to sea of maturing eels, the native climax animals in the food chain.

RIVER POLLUTION—The photographs illustrate common forms of this nuisance. The existing law is inherently partial and affords protection to some types, requires proof of actual damage in the case of others and expressly proscribes some which are possibly no more harmful.



Sawdust — seepage from impounded sawdust entering a Westland (Sth. Is.) river. Periodically the accumulated waste itself is flushed into the river. Sawdust is an expressly proscribed pollutant under the Fisheries Act, 1908. (Plate XIX.)

Mining—a man-made depression from which about 2,700,000 cu. yds. of spoil have been discharged into the Inangahua River (West Coast, Sth. Is.). Discharge of mining wastes is lawful in most parts of New Zealand. (Plate XX.)

Milk Wastes—sewer moulds fouling bed (see foreground) of a rapid Taranaki river, 60 ft. below outfall from cheese factory. This wastage of economically valuable whey is common in dairying districts. (Plate XXI.)

General Refuse—litter observed several years ago in a stream in a North Island national park. No legislation of general application aims at the preservation of the amenities, as such, on streams from this type of irresponsible action. (Plate XXII.)

Slaughter House Wastes—The photograph fortunately does not record the stench from the fouling (left foreground) of this beautiful Taranaki (Nth. Is.) trout stream. Under fishery laws proof of actual harm is necessary in cases of pollution by meat or milk wastes. (Plate XXIII.)

If man is to improve the fertility of inland waters, his efforts are most likely to be fruitful if directed (1) to waters which have basic deficiencies, (2) to those of them where nutrients will be used and not carried to sea, and (3) to those where nutrients added will, because of favourable physical conditions, be most likely to have an appreciable effect—that is to say, to shallow rather than deep lakes.

In waters where spawning facilities are used to capacity, fertilization cannot be expected to change the numerical abundance of trout. It can be expected to change the rate of growth of trout only if growth is at present inhibited through insufficiency of food rather than temperature or other conditions which may affect the appetite. Again, improved growth of trout, at the top of the food chain, will not result if there is a non-chemical limitation at some intermediate point in the food chain. For instance, the addition of inorganic compounds to lake waters may stimulate the production of minute plant organisms and thereby increase the amount of zooplankton. There, for all practical purposes, the process may stop unless there exist small fishes capable of using the increased plankton and, in effect, accumulating it in particles large enough to interest trout.

Under conditions of extraordinary local concentration of plankton (principally *Daphnia*), the writer observed large short-finned eels in Lake Poerua and bullies (*Gobiomorphus sp.*) in Lake Brunner feeding on it. In New Zealand, trout have not been observed feeding on plankton in lakes. Commonly, the conversion of plankton into food for any except very small trout is much dependent on the abundance of small surface-feeding fishes (*Retropinna* and *Galaxias spp.*). As it has yet to be learnt what essential environmental requirements limit the abundance of these fishes, it is unsafe to assume that food is always, or even usually, significant in this respect. With regard to bottom-living forms of life in lakes, present knowledge of their habitat deficiencies and inter-relationships is too inadequate to enable the ultimate effects on trout populations to be foretold if, through fertilization, increased algae are produced.

Plankton animals are not found in New Zealand rivers. Soluble nutrients are used by diatoms which comprise the basic vegetable matter on which many benthic forms of life are directly, and trout indirectly, dependent in streams. The instability of many New Zealand streams is such, and the regeneration of diatoms in them after flooding is so rapid, as to raise doubts as to whether any useful purpose would be served by adding nutrient matter. Evidence of destruction of the diatom covering of the beds of streams by flood action is commonplace. A physical deficiency in stability cannot be remedied by chemical treatment. Even in stable portions of streams, fertilization may not help. Earlier, reference was made to stable and richly diatom-clad gravels in parts of the Waikaka in Otago and the Waipa in Auckland. These gravels are deficient in mayfly and caddis larvae not because of a deficiency of their food, which is most abundant, but apparently because the stones on the surface of the beds are partially embedded and these do not offer the essential cover on their under sides.

Even in small rivers, the quantity of water passing down is such that several tons of fertilizer would need to be used to add appreciably to the fertility of the water. A small stream with an average flow of 20 cusecs would probably require

one and a half tons a year to produce any effect, even for a short distance below the point of application.

With very few exceptions, fertilization of waters has been applied only to small and shallow ponds used in Europe principally for rearing carp and in the United States principally for rearing bluegill bream and bass. Even in the case of small ponds, there is no universally accepted practice. In Europe, organic manures, including domestic sewage, have long been used. In the last 20 years, inorganic compounds especially have received more attention. In the United States, the use of organic manures has sometimes not been favoured because they stimulate the growth of filamentous algae. In England, Macan, Mortimer, and Worthington (1942) have emphasized the need for overcoming lime deficiencies as a first step, and have then found phosphate manures most beneficial and potassium commonly useful. They find that nitrates and ammonium salts give variable results, and they regard present knowledge as insufficient to recommend their use. The quantities they recommend, apart from so much lime as may be needed to bring the pH to 7 or better, would cost about £1 per annum per acre of water 6 or 7 feet deep. Fertilization is not carried to the stage where large submerged vegetation is killed because penetration of light is reduced by the density of plankton produced, as is recommended by Davidson and Johnson (1944) in the United States. The latter authors, advising on the production of bream and bass in artificial ponds 6 to 8 feet deep, recommend a fairly standardized treatment with mixed fertilizers at the rate of 800 to 1,000 lb. an acre. This would cost £4 to £5 per acre per annum in New Zealand. It will be apparent that costs could vary greatly and would commonly be much more if similar results were to be sought from deeper lakes and lakes through which considerable volumes of water pass.

The practicability of artificial fertilization of rivers and large lakes in the interests of trout fisheries has yet to be demonstrated as an economically sound venture. Fertilization is known to have given appreciable results in small and shallow ponds, usually where the food chains have been fairly simple ones and the climax fishes have been carp or bass. Present knowledge does not hold out hopes of obtaining returns commensurate with the cost by haphazard additions of chemical compounds to trout waters in general. There do not appear to be any insuperable difficulties in obtaining, by artificial fertilization, some improvement in the food resources in some of the shallower lakes of New Zealand, should this be found necessary.

The most extensive series of shallow lakes in the country is that lying in the western coastal belt of the North Island, all of which already contain food. In none of these lakes has it yet been found possible to establish a self-supporting stock of trout, and in only two have appreciable returns so far been obtained from regular artificial stocking. Much more information is required about the life histories of plankton-eating fishes and about the ecology of various forms of benthic life and the feeding habits of trout in New Zealand lakes if fertilization, even of small lakes, is to be other than a highly speculative venture. Reasonably economical use of fertilizers calls for sound knowledge of chemical and physical features of the environment to which they are to be applied. Particularly, it calls for an appreciation of Liebig's rule. This is that production is proportionate, not to the sum total of all nutrient substances, many of which may be present in

excess, but to the quantity of the essential one which is found in minimum quantity relative to the demand.

Depending on the rate of application, the present New Zealand costs of chemicals alone for treatment of lakes at the rates found effective in Europe and North America would be between £700 and £3,500 per square mile of lake water per annum, for water only 6 to 8 feet deep. The costs would, of course, be greatly more if the water were deeper. Even in the case of shallow lakes, there can be no certainty, without prior investigation, that appreciable improvement of trout stocks will result from fertilization. At the most, present knowledge suggests that investigation might lead to a sufficient reduction of costs to make fertilization a practicable venture in certain small lakes where the chemical deficiencies are simple and involve cheap compounds and the physical conditions are not unsuitable and where, because of an abnormal demand for angling, an unusually high maintenance expenditure may be warranted.

Environment Improvement — Biological

While it is clear that chemical and physical changes in environments will be reflected by changes of a biological nature, the possibilities considered here are those of a direct kind involving the addition or removal of species. The establishment of further species of game fish was considered earlier. There remain questions of introducing food and questions of controlling predators.

FOOD

Certain major successes in the acclimatization of animals in New Zealand predispose the angler to favour the introduction of food for trout waters. The easy and almost alarming successes which followed the introduction of rabbits and deer were understandable, as they had no predators nor competitors. Brown and rainbow trout were established and multiplied in many waters despite competition and predation, most conspicuously on the part of eels and shags. Yet, through insufficiency of knowledge of their environmental requirements, substantial failure resulted from the great majority of attempts to establish Atlantic salmon, quinnat salmon, sockeye salmon, and American brook trout, and total failure followed releases of whitefish in several lakes and cisco herrings at Rotorua. Of these, the cisco herrings alone were released in a lake which appears remarkably rich in native fishes (*Retropinna sp.*), which could consume plankton. The whitefish, which are specialized plankton feeders, were released in waters which appear deficient in plankton—certainly more deficient than in nearby lakes into which these fish were not released. Large pond snails (*Limnaea spp.*) alone have been imported and established as food in some New Zealand waters, but their significance as trout food in such waters has yet to be demonstrated.

Transfers of native fishes to inland lakes are known to have been made by Maoris before the European settlement. Abortive attempts to establish eels in Lake Taupo are recorded by Hector (1880), but there is no certainty that a race, in whose dietary fish had such prominence, would have limited its efforts to eels, nor to Lake Taupo.

Since the establishment of trout, it is known that in Canterbury the late J. S. Main transferred fishes (*Gobiomorphus sp.*) and possibly other forms of food to

inland lakes, but no records were kept of such transfers. However, there are records of apparently abortive attempts to establish the freshwater prawn (*Xiphocaris*) in the lower portion of the Selwyn River, in Canterbury, and at various times from 1908 onwards in Lakes Rotorua and Taupo. More recently smelts (*Retropinna sp.*) were transferred from Lake Rotorua to Lake Taupo and other lakes. It would appear from Hector (1902) that smelts were previously present in Taupo.

It is evident from past experience and from knowledge of the highly specialized requirements of different life forms, as described by Percival (1932) and other writers, that attempts to introduce food cannot be expected to succeed unless they are made with knowledge of the environmental needs of the animals concerned and with knowledge that these needs can be met in New Zealand.

Transfers to new environments of native species appear to offer very limited possibilities of success, As regards most of the components of the invertebrate fauna, which go through winged stages, it seems probable that their natural distribution is in accordance with their specialized environmental needs and that attempts to broaden their distribution would fail for want of favourable unoccupied environments. Indigenous fishes, crustaceans, and molluscs may offer more scope for transferring species to new environments, but it would appear to be limited largely to isolated lakes and upper portions of streams above falls. Even in such cases it should not be attempted without direction from biologists, so that needs and prospects may be first considered and effects later observed and recorded.

It should be a condition precedent to the introduction of trout food that there is actually need for additional food where the proposed introduction is to be made.

Rivers with loose, unstable beds and falls of 20 to 30 feet per mile, such as the Waimakariri, on the Canterbury Plains, are more deficient in animal life than more stable streams of less gradient which also flow across plains of alluvial gravel. However, it is not known that there is insufficient food for such trout as are found in them, nor would it be easy to find outside New Zealand animals capable of thriving under the conditions offering without competing with indigenous forms already present.

There are other streams of a relatively stable nature, such as those comprising the Bruce Stream, or eastern branch of the Orangipuku River in Westland, in which very few post-yearling trout remain during the angling season. This fact is despite the substantial production of fry of lake-reared brown trout and despite abundant cover and food. Moreover, the known physical conditions are suitable and the very varied fauna comprises forms found in association with trout elsewhere. It is quite unsafe, without proper investigation, to attribute paucity of trout or small size of trout in portions of New Zealand waters to insufficiency of food.

Subject to the need for additional food being demonstrated, the selection of suitable animals should proceed from a knowledge of the potentialities of physical and biotic environments in New Zealand. There should first be consideration of what gaps or inefficiencies occur in food chains here rather than of what known useful food elsewhere could be transported to New Zealand. The aim should be to bring in something capable of converting vegetable and animal matter, at present not used, into food for trout and of bringing in forms likely to prove competitive

with indigenous forms only where they will displace forms of little use or when they will reduce wastage by shortening food chains. Instances which follow are given for purposes of illustration, and are based on general impressions rather than on the more careful surveys which would be necessary to warrant specific recommendations.

Unpublished notes by Professor E. Percival on plankton collected by him and the writer in 17 lakes in the South Island show that there is much difference in the density and composition of the plankton fauna of these waters. Where, as appears sometimes to be the case, indigenous fishes fail to become sufficiently numerous to make efficient use of the plankton resources, there is a prima facie case for introducing small fishes capable of converting more plankton into food for trout of medium and large sizes.

Diatom and detrital feeding crustaceans are abundantly represented in brackish coastal lakes, such as Ellesmere and Waituna, by the phantom shrimp (*Tenagomysis*) and in the Tomahawk Lagoons by a highly localized sow-bug (*Asellus*?). The freshwater prawn (*Xiphocaris*) is generally much restricted to the vicinity of tidal waters, except in slow-flowing streams in the northern portion of the North Island. Although indigenous shrimps (*Gammarus spp.*) are sometimes found in small numbers, there is a paucity in most inland waters of crustaceans intermediate in size between the small water-fleas (*Paracalliope spp.*) and the freshwater crayfishes (*Paranephrops spp.*). Among the freshwater shrimps, scuds, and water-lice or sow-bugs of Europe and North America, known to be useful as trout food, species may possibly be found capable of thriving and providing food for trout of intermediate size here.

The only pond snails which are widely distributed and abundant in New Zealand are of small size. They are consumed by inanga (*G. attenuatus*) and to a limited extent by bullies (*Gobiomorphus spp.*) and by trout. The only large native aquatic snail (*Melanopsis sp.*) is a heavily-shelled form, and much restricted in its distribution. There appear to be lakes and stable waters where the large European species *Limnaea stagnalis* (already introduced) and *L. peregra* and possibly some of the large North American forms might prove useful.

Burrowing types of mayfly nymphs are represented in New Zealand by *Ichthybotus*. It is possible that the several genera with similar habits in Europe and North America may include species suited to a greater diversity of types of stable sand and silt bed than the indigenous species occupies. Burrowing types are usually of large size. Some occur in lakes from which mayfly nymphs are usually absent in New Zealand.

The possibilities discussed are mainly of forms of life suited to still or sluggish waters or to streams with stable beds. The possibilities of finding forms suited to the many trout streams of New Zealand which possess shingle beds, often of very limited stability, are less evident. Whether additional species of the mayflies, caddis-flies, and midges, which in their aquatic stages are vegetable feeding, could be accommodated is not known. In waters where fingerling trout and other small fishes are scarce, but larger trout are present, the conversion of midge larvae and smaller mayfly nymphs into larger particles by carnivorous caddises (*Rhyacophila*), stoneflies, Dobson flies, and the mayfly (*Ameletopsis*) in their aquatic stages is probably beneficial. Whether additional carnivorous invertebrates or small

fishes are desirable could be determined only from a study of the relative abundance of vegetarians and carnivores and the needs of particular populations of trout in the particular parts of different streams.

Consideration of the need for food supply and the possibilities of additions by the establishment of imported species should have a proper place in any long-term plans for development of inland fisheries. Most of the useful components of the faunas of trout streams in other countries have their counterparts in the faunas of trout streams in New Zealand. The environmental requirements of all components are to some extent specialized. Inter-relationships are more often complex than simple, and are still so little known that the effects of introducting new species cannot be foretold with any degree of certainty. **In order to minimize disappointment, waste of money, and possibly unwarranted efforts, the introduction of trout foods should be left to the direction of biologists, who might favour the introduction of particular forms when it is demonstrated as a reasonable probability that—**

(1) Additional food is needed.
(2) Life forms useful as food and suited to the environments offering can be introduced.
(3) Food and other environmental essentials will be available for such animals without the displacement of valuable indigenous forms.
(4) Life forms introduced will not have harmful characteristics.
(5) Their introduction will be so controlled that noxious forms of life—parasitic or otherwise—will not be accidentally introduced with them.

PREDATION AND COMPETITION

Eels

The presence in most trout waters of very great quantities of eels is evidence that the food resources of different waters produce a great weight of fish flesh additional to the trout flesh produced. Records of captures made by the Southland Acclimatization Society in the Hedgehope River show that in 1937–8 quantities of long-finned eels (*A. dieffenbachii*) weighing approximately 2,000 lb. per mile of stream (approximately 15 ft. to 30 ft. wide) were removed. The progressive decline in the energetic exploitation of eels by Maoris, especially in parts of the North Island, must have permitted an increase in size and abundance of these fish. At Inchbonnie, in Westland, in 1934–5 the writer collected long-finned eels which were feeding principally on the aquatic stage of caddises and mayflies, the main food of trout of from 3 to 10 inches in length in the same streams. In addition, eels ate trout fry. Cairns (1942) showed that the food of long-finned eels of 16 to 30 inches in length collected from a much wider range of waters, comprised principally caddis larvae and mayfly nymphs which other writers had shown figured most prominently in the food of trout of medium size. Further, he found that trout occurred more commonly than any other type of food in long-finned eels of more than 30 inches, which, with increase of size, tend to become exclusively fish-eaters.

The facts that eels compete with trout for food and feed directly on trout and are so very abundant suggest that control of eels might make possible a substan-

tial increase of trout. Control would aim at making available for man, the predator, what has hitherto been taken by the predatory eel. The effects on trout populations of reduction of eel stocks cannot be foretold with any certainty. The effects could be expected to differ in different waters according to the relative quantities of eels and trout in them and the degree to which they use available food resources. It would seem certain that some numerical increase of trout would result from effective control of eels and that for a time additional food would be available. However, it must be ascertained whether the destruction of eels would make available a quantity of food sufficient to support the trout which those eels would have destroyed. Whether this question is of practical significance is not known, and it is unlikely to be one having an equal significance in all waters. While there is a great deal of recorded evidence of the harm eels do in trout waters, there is as yet no recorded evidence of the effects of such attempts at control as have been made.

In the case of other fishes in North America, there is evidence of the successful clearance of unwanted species from small lakes and streams by poisoning and the subsequent development of useful fisheries in them. At Cultus Lake, species harmful to young sockeye salmon were greatly reduced by systematic netting, and the survival of salmon until the time of seawards migration was thereby increased to as much as three times what it had been. (Foerster and Ricker, 1941.) An interesting feature of this study was that the resultant increase in value of salmon was estimated at about nine and a half times the cost of destroying the predators.

Before considering the feasibility of controlling eels, it is necessary to cover briefly the principal features of their distribution and their habits in fresh water.

Schmidt (1927), in a preliminary note, suggested that the short-finned eel (*A. australis schmidtii*) belonged mainly to the north and east. In 1936, I collected this species in the coastal areas of Otago and Southland and inland in lakes in Westland. Ege (1939), reporting more fully on the Dana collections, showed occurrences of this species on both the south and west coasts of the South Island. As early as 1926, Mr. A. E. Hefford, when organizing collections of eels for Schmidt, had suggested that the short-finned species should be sought in stagnant ponds and lagoons rather than in running water in Southland. Later, Cairns (1942) showed more generally that the short-finned eel is usually restricted to the vicinity of tidal waters, but occasionally extends its range far inland in more sluggish streams and lake-controlled waters. As has been long established for other species overseas, the males of both species were not found to travel inland beyond the limits of tidal waters. Thus the large eel common in most trout streams and lakes is usually the female of the long-finned species.

Eels enter from the sea in spring and early summer. They then live a semi-subterranean life buried in the mud and in stable boulder banks until they reach a length of 12 to 14 inches. During this time they emerge for only short periods each year to journey farther inland. This secondary upstream migration was observed by the writer in the Arnold River, in Westland, in December, 1934, and has been noticed by various writers in other waters, usually in December or January. It will be noticed that eels are rarely available to trout as food until they attain a size too large to be taken by any except very large trout.

Studies by Cairns (1942) are in close agreement with earlier studies by McFarlane (unpublished ms.) as to the rate of growth of small eels. It would appear that they are commonly two years old when they enter from the sea, and usually a further seven years elapse before eels, at a length of 12 to 14 inches, begin to travel freely in the water to feed.

Commonly because of choice of habitat and the smaller size attained, the short-finned eel does not compete with or prey upon trout. The females, which are larger than the males, migrate to sea from Lake Ellesmere usually at a length of about 27 in., and from Lake Forsythe at about 33 in. A few exceptional fish pass the size of the smallest of the long-finned female migrants. Captures at Ellesmere in 1942 included three migrant short-fins of 4.5 lb. to 5.75 lb. One taken in March, 1948, from the outlet of Lake Clearwater was 42 in. long and 5.5 lb. in weight.

The size attained in most waters before long-finned females migrate to sea as maturing fish is not known. Cairns states that the main run of long-finned females comprises fish of about 90 cm. (36 in.) in length. Fish of this size would weigh about 4.5 lb. He shows that approximately 25 per cent. of the long-finned eels of over 75 cm. in length, taken in the summer and containing food, had eaten trout. It is therefore of great practical importance to know how long these eels remain in fresh water after passing 75 cm. in length and the usual size attained before migrating.

In the Lake Ellesmere system in 1942, observations were made by the present writer throughout the time during which maturing eels of this species sought to go to sea. A typical series of 177 females averaged 47 in. in length and 13.2 lb. in weight. Thus eels reached approximately three times the weight Cairns considered they did, and it seems that the additional weight was attained substantially on a fish diet. The average age of eels of this size, as suggested by a few age determinations of eels of large sizes from other waters, made by Cairns (1942), might be 18 or 19 years. It would appear from the foregoing that, if the entry of further young eels into a stream was prevented, a period of about 16 years might elapse before most eels already present had migrated seawards; alternatively, if all eels now present were removed, a like period would elapse before replacement was completed. Again, replacement might take up to nine years following the removal of all eels above 12 to 14 inches.

Eels populate all waters to which they can obtain access from the sea, and sometimes reach lakes by non-permanent outlet streams, as at Lake Mason, in Canterbury, and possibly in some cases (for instance, Virginia Lake at Wanganui) by subterranean seepage streams. Falls in streams may not prevent access, if wet rock walls permit small eels to climb. Rapid water accessible to trout may prove impassable to eels, as is the case at Okoroire, in the Waihou River, and as formerly occurred in the vicinity of Arapuni, in the Waikato River.

It is not known what determines the density of population attained by eels in different easily accessible waters. There is, however, much to suggest that the type and amount of cover available is of greater importance to eels than to trout, whose requirements of cover may be satisfied by depth of water alone.

Extermination of long-finned eels in New Zealand waters is something so remote from immediate and practical possibilities that it need not be considered

here. At present, it is justifiable to experiment with control measures and, on the basis of the results obtained, to consider how far their extension is warranted. The quantities of eels in different waters are so great that funds and energies could be dissipated to little advantage, unless their outlay proceeded according to a plan devised to minimize wastage. In special cases, to be discussed later, it should prove possible to deny eels access to waters and thereby to obtain a substantial effect for a small outlay. However, in general, efforts should be directed in the first instance against eels in the heavily fished waters closest to population centres. In such waters the need is greatest for more trout and also the probability of capture of any additional trout made available is greatest.

In the initial stages of a campaign, control would be better applied to small and simple river systems rather than to large and complex ones, for the elimination of eels of harmful size would be more thorough in smaller waters, and rapid redistribution, such as might follow clearance of parts of a larger system, would be avoided. Further, better opportunity would be afforded of learning the effects on trout populations by systematic clearance than by dispersed and less thorough destruction. Again, a mere culling of the eel stocks might tend to be offset by the enhanced opportunity of survival of escapers through reduced competition.

In a major district a planned campaign might provide for the systematic tackling of the eel problem in a succession of streams over a period of eight or ten years and then recommencing on the first stream. The feasibility of controlling eels in major water systems could best be judged on the basis of experience gained in working smaller systems. Where, as is the case in some districts, potentially valuable small independent water systems are lacking, efforts should be directed to the systematic destruction of eels in tributaries which contain the principal trout-spawning areas. In them trout are especially vulnerable because of their small size, and the predations of the individual eel are most effective because the concentration of prey makes capture easy. The benefits of clearance of eels from spawning tributaries might be lost within a short time if in a tributary system there were reservoirs, swamps, or muddy creeks from which repopulation could take place.

The most appropriate methods of control would depend to some extent on local conditions. The following possible opportunities of control should be contemplated:

(1) *Denial of access* to trout waters (a) by modification of natural waterfalls up which eels at present climb, (b) by the construction of weirs passable to trout but impassable to eels in streams of fairly even volume, such as the outlets of certain lakes, and (c) by the provision in dams built for hydro-electric and other purposes of fish ladders designed to give access to trout but not to eels. The advantages of this method are that for an initial outlay permanent riddance may be obtained. Effects would become apparent progressively as, over a term of years, fish migrated downstream, but the process could be speeded up by active destruction of the eel stock above such a barrier. Denial of access to eels has sometimes been an accidental result of the construction of dams, but was attempted as a deliberate policy in 1938, when a dam in the Arnold River, in Westland, was reconstructed. Costs would prohibit the use of this method in most waters, but the occurrence of natural falls in some districts and of small lake-controlled streams in others

and the development of hydro-electric power schemes elsewhere provide opportunities worth considering.

(2) *Trapping of elvers* as they travel inland each spring. This practice has been followed for a very long period in the British Isles and in France to obtain supplies for sale rather than as a control measure. The methods found effective elsewhere might be suited to some New Zealand streams. This migration takes place usually at night, but may be observed by day in some of the opalescent waters of the North Island and may occur more generally by day in waters discoloured by floods. As upwards of ten years would elapse before any benefit could be expected, the method is best suited to use in conjunction with others.

(3) *Trapping young eels* during the secondary migrations which occur each summer. The evidence of this movement comes almost wholly from waters where obstructions prevent easy upstream movement, but doubtless such movements occur in rivers generally. There is need of information as to the distance upstream reached by elvers, the points from which the secondary migration (or migrations, for a number of year-classes are involved) begin and their extent, the behaviour of the fish when travelling, and the duration of their movement. The possibilities are especially worth investigating because, in conjunction with other methods, they would enable an attack to be directed against the whole stock.

(4) *Capture of large eels* that have reached a size at which they move freely by night to feed, principally from October to April. At this stage, fish are readily attracted to baited pots. The possibilities of these fish entering sluggish reaches, marginal swamps, and stable tributaries of unstable shingle streams to hibernate and leaving such grounds again in the spring are suggested by rather fragmentary evidence. If such movements were confirmed, they would offer additional possibilities of trapping.

(5) *Trapping maturing downstream migrants.* This method might permit the capture of the greatest quantities for a moderate expenditure, and might therefore be useful as a means of reducing the average cost of capture of eels taken throughout the season and thereby encouraging commercial utilization. In other respects, it offers little hope of improving waters for trout, for there is no evidence of return of spent eels from the sea and no evidence that progeny return to the stream selected by their parents and, as yet, there is no likelihood of control measures being applied to a sufficient number of rivers to reduce significanctly the number of elvers returning from the sea.

(6) *Poisoning* of noxious fishes in small lakes and streams has been done in North America. Heavy concentrations may be necessary where there is a deep mud bed. Although the method has been directed against other species, its use against eels in small waters, subject to proper safeguards, may be warranted. After an interval, assisted repopulation of such water with useful fauna could take place, and, because of the slow growth of eels, a succession of crops of useful fish might be taken before complete repopulation by eels occurred. Narcotics, irritant chemicals, and electric currents have all been used to aid the clearance

of fish from streams. Under proper control, in specially suitable conditions, all of these methods might be employed against eels.

Eel control cannot yet be recommended as a final policy, because at this stage there is not enough knowledge as to the costs of control or the effects on trout populations. There is, however, ample evidence to recommend its adoption as a promising line of provisional policy which should contemplate experimental application of control measures to selected waters, the systematic recording of methods, results, costs and effects and, later, the possible more general application of control in the light of experience gained.

Shags

Three species of shag, or cormorant, occur on inland waters in New Zealand. One of these, the little black shag, is a protected bird under the provisions of the Animals Protection and Game Act, 1921–2. This is a small, wholly black species (*P. sulcirostris*) restricted in its freshwater range to Lake Waikare in the lower Waikato basin and to more northerly waters.

A second small species, the white-throated or little pied shag (*P. brevirostris*), shows much variation in plumage. Individuals may be almost wholly black, white-throated and sometimes white-breasted. This bird is widely distributed in the North and South Islands, but is numerous in few areas. The writer's impressions are that it is a much less wary bird than the large black species, that it avoids rivers with open shifting beds and prefers coastal lagoons and tidal reaches of streams, but it may be found far inland on lakes and relatively stable streams. It is generally uncommon inland on the eastern side of the South Island, but is a common bird on portions of the Waikato and Waihou basins in the North Island. Falla and Stokell (1945) report that 40, taken over a period of seven years at Lake Taupo, contained bullies, galaxids, carp, and fresh-water crayfish, but no trout. One examined by the present writer from the upper Waihou, in Auckland province, contained two rainbow trout; twelve from the Little Waipa River, a few miles distant, all contained crayfish, with the addition, in one case, of fish remains. Records of the Waimarino Acclimatization Society show that eight birds contained 17 trout, 15 bullies, and 8 crayfish. Six specimens from the lower Wairau Valley in Marlborough examined by the late Maurice Hope or the writer contained six trout, five small eels, two crayfish, and one flounder. All of a number of these birds taken by the Southland Acclimatization Society on Lake Monowai were reported to contain bullies; one had 14. Four others from different inland waters in the same district contained fourteen trout and seven bullies.

Impressions of this bird in relation to trout fisheries are that inland through the South Island it commonly occurs in numbers too small to provide material for a proper investigation of its feeding habits and that, because of its scarcity and the indicated varied nature of its food, it can have no significant effect on trout fisheries. In the central and northern portions of the North Island, it is sometimes sufficiently numerous to warrant an investigation of its inter-relationships with trout to decide whether or not control is desirable. The white-throated shag is an attractive-looking and fairly tame bird; general measures for its control are not justified by such evidence as is available.

The large black shag (*P. carbo*), because of its size and fish-eating habits and its lack of beauty, has for long been hunted by angling interests. The bird's apologists have advanced the conflicting arguments that it is valuable to trout fisheries because it eats eels which prey on trout and because it thins out populations of trout and thus prevents overstocking. Further, some consider that the trout is an interloper, and that the shag, as a native bird, is inherently worthy of protection. Such action might be warranted if the bird were a rare species peculiar to New Zealand instead of being universally distributed and if its local extinction were intended. Again, if it were a beautiful bird, familiar as such to a larger section of the public than the angling section who consider it harmful, provision for its protection, in areas where some appreciable section of the public could see it, might be warranted. However, the writer can see no reason for requiring an abnormal amount of evidence to justify its control, provided always that there is sufficient evidence that on balance the bird is harmful to a significant degree to trout fisheries and provided that control measures are taken only where there is evidence to warrant such a course.

Falla and Stokell (1945) report only eels, 20 in 11 specimens of large black shag from Lake Waikare in the lower Waikato basin. They report the identification of five trout, one carp, and one galaxid in seven birds containing food from Lake Taupo in the upper Waikato basin. Lake Waikare, so far as is known, is devoid of trout and Lake Taupo is devoid of eels. Fish identified by the same authors from 11 birds from Lake Ellesmere, a shallow, brackish sheet of water on the coast of Canterbury, were nine eels, one flounder, and 24 bullies. Their further collections from two Canterbury rivers comprised five adult birds, three flying young, and 17 nestlings. The identified fish in them were trout and bullies. In addition, they contained miscellaneous matter, mainly caddis larvae, in greater quantity than was found in other collections. Such matter may have been taken directly by the large birds or indirectly in the guts of fish devoured. On this point, material examined by a biologist for the Wellington Acclimatization Society gave the following results:—

6 Birds containing no fish or fish remains:
Occurrences of caddis and miscellaneous food 0

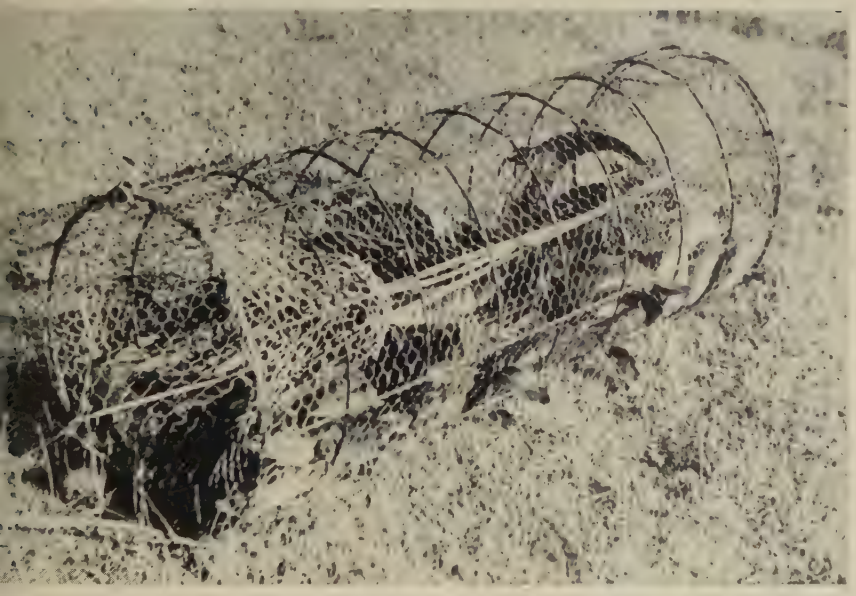
15 Birds containing identifiable fish only:
Occurrences of caddis and miscellaneous food 4

13 Birds containing identifiable fish and fish remains:
Occurrences of caddis and miscellaneous food 12

20 Birds containing unidentifiable fish remains only:
Occurrences of caddis and miscellaneous food 8

These 54 birds and 11 examined by one of the Society's field officers were taken from more than 12 localities in the Wellington province, and included birds which had been feeding in upland streams and in lowland lagoons. Apart from unidentified remains, they contained 31 trout, 11 carp, 8 eels, 1 lamprey, and (in one bird) 50 small fish like whitebait. The late Maurice Hope reported that seven large black shags, from four areas in the upper shingle areas of the Wairau system, in Marlborough, all contained trout, a total of 30. From the same river system, near and on the coast, five birds contained three trout, one eel, and unspecified numbers of flounders, mullet, and (in one case) other unidentified marine fishes.

Setting an eel basket where it is likely to do most good—where extensive areas of stable gravel for spawning lead to an unusual concentration of resultant young trout and where plenty of food and cover make for abundance of eels. (Plate XXIV.)



The same basket next morning —29 eels weighed 113 lb. Twenty per cent. of eels examined in this stream contained fingerling trout. The creek is a stable tributary of the loose shingle-bedded Whitestone River in Southland (Sth. Is.). The Southland Acclimatization Society has actively assisted research on eel-trout relationships and supported the commercial exploitation of eels. (Plate XXV.)

Large long-finned eels, including a 32 lb. fish, from the lower portion of the Doyleston Drain—a valuable trout spawning tributary of Lake Ellesmere in Canterbury (Sth. Is.). The eels are being taken for cannery purposes. (Plate XXVI.)

MUDDY CREEK

(Lake Alexandrina—South Canterbury District).

One of two spawning tributaries of rainbow trout entering Lake Alexandrina from which eggs have been collected for hatching and return as fry. In March, 1948, there was a great abundance of wild fingerling rainbow trout in the vicinity photographed, where eight eels taken weighed 54 lb. and included a 14½ lb. fish. Five eels contained trout. Control of these predators in nursery waters might give a better return than artificial propagation. (Plate XXVII.)

LAMBIES STREAM

(Lake Clearwater—Ashburton District).

The outlet stream of Lake Clearwater. Brown trout of 3–6 lb. run down-stream from the lake to spawn. The protruding tops of redds can be seen. Where large trout accumulate in so small a stream so close to a road, a stock is highly vulnerable to poaching. Naturally produced fingerlings and second year trout abound. Some are preyed on by eels which range up to about 16 lb. in this creek. (Plate XXVIII.)

It will be observed from the foregoing records that the food of the large black shag varies according to the food available where it chooses to feed; doubtless, a wider range of foods would be shown if material was collected from salt water. To what extent it selects or shows preference for special foods of those available where it chooses to feed is not known, except that generally fish of one kind or another comprise the bulk of its food. Present evidence simply shows that it feeds on such food as is available. There is no evidence that it chooses certain areas because of the abundance of any particular kind of fish or that its distribution is even principally governed by considerations of abundance of food in general.

The bird is known to nest and roost especially on cliffs on the sea coast and in trees overhanging or near streams or lakes inland. Suitable cliffs are found only on parts of the coast, for example, round Banks Peninsula, and suitable inland sites vary in local abundance.

It is not known whether there are seasonal changes in the feeding grounds of the coastal and inland colonies, to what extent interchange and recruitment of one stock from the other takes place, or, indeed, whether colonies remain, throughout the year, sufficiently distinct to warrant separate consideration.

To sum up the evidence as regards the North Island and Marlborough and Canterbury in the South Island, it is clear that a general condemnation of the black shag is unwarranted. The bird is shown to feed largely on trout in inland waters which contain trout, and largely on eels in shallow lakes and lagoons. A mixed diet in which trout, eels, flounders, and mullet are conspicuous is taken in some tidal waters. The shag is not shown to be beneficial in any way to trout fisheries, for the only eels consumed, which were specifically identified, were of the short-finned species (Falla and Stokell—Lake Ellesmere material). This species is not known to attack trout. It is usually of a more suitable size for shags to eat, and is the numerically dominant eel at Lake Ellesmere and in the lower Waikato basin and generally in coastal lagoons and sluggish tidal reaches of rivers, where shags have been reported most frequently to take eels. The evidence, so far as it extends, suggests that, on inland waters in the parts of New Zealand under discussion, the black shag is harmful rather than beneficial to trout fisheries.

Too little is known of the total number of birds frequenting inland waters to enable the significance of their depredations in New Zealand waters generally to be assessed. Falla and Stokell discuss numbers of birds in the North Island and in Marlborough and Nelson. The numbers reported to them may or may not be correct, but in the aggregate they suggest that the black shag is greatly less abundant inland than is suggested by annual reports of the Department of Internal Affairs. Reports for the four years ended March, 1941, show that the mean annual number of shags destroyed in the Taupo and Rotorua districts was 1,311. Thereafter the total fell, at a time when ammunition was difficult to procure and most able-bodied men were in the armed services. Reports from acclimatization societies do not usually give clear statements of the numbers of shags destroyed and places where they were killed. More often they give the amount spent on bounties, sometimes without specification of the amounts for different predators and often without clear statements as to numbers destroyed by their staffs.

Evidence of the feeding habits and local abundance of the large black shag in fresh waters in the southern half of the South Island is given by Williams (1945).

Additional information, especially as to locations of collection of material of more than two-thirds of the specimens, was earlier circularized among acclimatization societies by the same author. These circulars indicate that less than 5 per cent. of the total specimens were taken north of the southern provinces of Southland and Otago. Further, these circulars and reports of acclimatization societies suggest that a very large proportion of the birds were taken by field officers of these societies.

Williams compiled reports of birds killed and examined by different individuals. The reports deal with 2,883 black shags from fresh-waters which were killed between 1921 and 1943. The recorded contents of the birds were: 15,903 trout, 182 flounders, 145 bullies, 132 perch, 73 mullet, 49 lampreys, 19 kokopu, 18 eels, 10 frogs, 12 crustaceans, and 4 marine fish. The facts that Williams relied on reports from sources he has not named rather than on material he examined himself and the proportionate representation of different fishes necessitate caution in appraising these results. The features which at first sight seem most remarkable are the relative absence of eels, the total absence of smelts and inanga, and, possibly, the small numbers of bullies. Smelts, inanga, and bullies are all consumed by trout, and, if found in stomachs with large, partially-digested trout, they might have been regarded as having been taken inside the trout and so ignored. Further, both these attenuated fishes, smelts and inanga, are very thin in cross-section, and would usually be digested more rapidly than larger species.

In sharp distinction to the position in the Waikato, Wanganui, and Manawatu, in the North Island, where, in slacker water, smelts and inanga travel far inland, they are not, in most Otago and Southland waters, found above very restricted tidal areas. Nearly all rivers of these two southern provinces carry coarse shingle down to the sea, and the short-finned eel, the distribution of which is similar to, but not identical with, that of smelts and inanga, is much restricted to the vicinity of tidal waters. The long-finned eel, which has yet to be shown to be an important food of shags anywhere, is plentiful in many waters of these districts. Comparative data on its abundance in northern and southern waters are not available. However, many southern waters, frequented by black shags, offer far less eel cover than is usual in northern waters, and those at high altitudes often appear to contain few eels.

The eel's availability is limited by its nocturnal habits and by hibernation, which may possibly extend for longer periods in the south than in the north. Except when streams are in flood, nocturnal habits seem to be departed from frequently only in streams with opalescent waters which are found in the northern portion of the North Island.

The generally higher sale of fishing licences in the southern portion of the South Island suggest a greater abundance of trout there than in most other portions of the country. Consideration of the foregoing facts suggests that a less varied diet, in which trout should be particularly prominent and eels somewhat uncommon, should not be remarkable for black shags on inland waters of Otago and Southland. The possibilities of some collectors tending to select material which would support their views cannot be wholly ignored, whether the collectors are anglers, as in the present case, or bird-lovers. Further, there are difficulties in identifying small partially-digested fish, and especially in determining whether shags have taken certain food purposely or inadvertently in fish. Such reservations

as the present writer has on these grounds in regard to the data compiled by Williams relate to the precise statements of quantities of different foods taken rather than to the general tenor of the results. It is accepted as well established by Williams that the black shag is principally a trout-eater inland in these two provinces, and that eels do not comprise a significant part of its diet.

Some assessment of the damage done to trout fisheries in Otago is possible on the basis of data provided by Williams and discussed in an earlier section. It was shown there that the annual consumption of trout by individual adult black shags was not less than 2,500. In the three nesting seasons—1926–7, 1936–7, and 1941–2—Williams took stock of the inland nesting colonies and found adult birds to number 2,546, 856, and 3,506 respectively. Thus the total annual consumption of trout by shags in the province is estimated at 6,360,000, 2,140,000, and 8,760,000 fish, principally of 7 in. to 11 in., in the successive periods.

Because of the greatly smaller numbers and size of fish released from hatcheries, it is to be expected that control of shags would have a much greater effect than would releases from hatcheries on the past scale. The practical benefit to anglers of the elimination of shags from inland waters cannot, however, be foretold with any degree of accuracy. This is so because many of the fish at present killed by shags could be expected to die from other causes before reaching the size at which they become available to anglers; further, of such fish as do reach legal size, only an unknown fraction is taken by anglers, for even in very heavily fished waters angling is not known to account for all fish which reach legal size.

While on present knowledge there is ample justification for acclimatization societies attempting to eliminate large black shags from trout waters inland, it is conceivable that the total quantities of trout usually present are so great that the depredations of shags are less significant than is commonly assumed. If this is so, the results of control may prove disappointing. The evidence in the case of the three species of shags considered may be summed up thus:—

(1) There is no evidence of the occurrence of the little black shag (*P. sulcirostris*) on trout waters in New Zealand.

(2) The scarcity of the white-throated shag (*P. brevirostris*) in most trout waters is such that it cannot be regarded as a serious factor affecting the numbers of trout. In restricted areas of the North Island, the bird is abundant, and it eats a variety of foods which include trout. There is need for further investigation of its feeding habits in such areas to learn whether it has a significant influence on the local abundance of trout. Meanwhile, its killing should not be encouraged except to provide specimens for study.

(3) The large black shag (*P. carbo*), in inland waters containing trout, feeds principally on trout, and is not found to be in any way beneficial to trout fisheries. The bird is widely distributed. Whether its depredations account for significant proportions of trout populations is not known, for there is insufficient evidence of the numbers of birds and of trout in different areas. In the southern portion of the South Island, its estimated consumption of trout greatly exceeds in number the output of local hatcheries, and consists of fish of much greater size than the hatchery product. Its estimated consumption of trout in number

greatly exceeds the angling catch, but comprises fish of much smaller average size. On present evidence, the control of this species on inland waters containing trout is justified. There is no reliable evidence as to what interchange of stock takes place between marine feeding, lagoon feeding, and inland feeding colonies, or to what extent feeding habits vary. Until such evidence is obtained, control should be limited to places where it will give the highest return; that is to say, to trout streams and lakes.

The payment of bounties for the destruction of black shags is an inefficient and uneconomical measure, for it assures neither adequate control nor the destruction of those colonies which are most harmful. Inevitably under a bounty system, shags will be shot where they are most easily obtained, often on sea cliffs or on coastal lagoons. If elimination, so far as may be practicable, of black shags on inland waters is desired, the work should be carried out solely by the field staff of societies, who can be required to do the work efficiently, where it is most necessary, and to keep proper records of the quantities of birds seen feeding on different waters, quantities destroyed, and the nature of the food found in them.

SHAGS AND FISH PARASITES

The control of shags in the thermal lakes area of the North Island has been attempted, less because of harm which trout suffer through direct attack than because a nematode worm, *Eustrongylides,* which infects trout, matures in water-frequenting birds, including shags. While it is known that heavy infestation may co-exist with poor condition in trout, good-conditioned fish often contain this parasite. There is as yet no recorded evidence which shows satisfactorily that condition, growth, or productivity of trout in New Zealand are influenced by the degree of infestation.

Stokell (1936) studied the nematode parasites of brown trout at Lake Ellesmere. He showed that unparasitized fish were better conditioned and more of them attained large size than fish infected with *Hedruris,* a brackish-water form of nematode which matures in trout. Further, trout infested with both *Hedruris* and *Eustrongylides* were poorer in condition than those in either of the other two groups, and the post-maturation growth of the older trout in this group was poorer. Stokell concluded from this evidence that both species were injurious to trout. The conclusion might be acceptable if it were known that fish comprising the three groups had lived and fed for a reasonable time under the same conditions. Stokell states that fish of extremely high condition were susceptible to infection. In speculating as to the cause of the infestation of some fish and not of others, he considered it probable "that certain trout, either from choice or owing to peculiarities of individual habitat, adopt feeding habits differing from those of the majority," and thus escape infection. As differences of feeding habits and of environments are usually fruitful of differences in growth and condition, it is not clear why Stokell should attribute the observed variation in growth and condition of trout to presence or absence of infestation rather than to these causes.

LIMITATIONS

The great expanse of river waters in New Zealand, the fact that such waters are not owned by fisheries authorities, and the lack of revenue sufficient to pay for substantial modifications of natural rivers for fisheries purposes make impossible the consideration of schemes of stream improvement on a scale sufficient to have any very wide and appreciable effects. The position may change gradually as population grows. There is still so much water per angler and so much lightly-exploited water, that, except where outside aid may be forthcoming, consideration may at present be limited to waters where unusual conditions render stream or lake improvement especially easy or especially necessary.

Such major physical changes as may in future be brought about in natural waters seem likely to result, not from the efforts of anglers, but from the damming of rivers for hydro-electric purposes and from the activities of Catchment Boards established under the Soil Conservation and Rivers Control Act, 1941. Generally, the activities of such boards, in so far as they aim at controlling run-off in hill areas of precipitation, should be beneficial if they tend to govern the rate of flow of streams and to increase the stability of their beds. The further activities of such boards in straightening and confining streams in lowland areas are not capable of general assessment, but it seems possible that they will often be harmful.

The probability of the activities of Catchment Boards affecting the nature and carrying capacity of streams suggested the need for the establishment of a liaison between local bodies and local fisheries authorities; this has been arranged. Such liaison also exists between the Marine Department, as the central fisheries authority, and the Soil Conservation and Rivers Control Council. There is need that fisheries authorities, which are themselves powerless to effect substantial changes in the character of any appreciable number of streams, should ensure that, when modifications of streams are planned for the benefit of any section of the community, the possible effects on fisheries should be assessed and taken into consideration.

Some such projects may, with slight modifications, be made beneficial or less harmful to fisheries without hurt to the principal end they are designed to serve. The Karapiro dam project on the Waikato River afforded an excellent instance of concessions willingly made to fisheries interests. These involved the provision of electrical deterrents to the up-stream passage of eels and the clearing of shrub growth from marginal shallows of the lake formed. Consideration was also given to the feasibility of diverting tributaries through prepared channels to provide spawning facilities to compensate for the destruction of spawning areas previously used.

Hereafter consideration will be limited to possibilities of effecting improvements to environments which may be within the capacity of Acclimatization Societies to carry out.

STREAM IMPROVEMENTS

There is to-day a considerable literature on methods of so-called stream improvement, but the amount of detailed descriptive writing on how to effect supposed

improvements vastly exceeds in bulk the research reports which show what changes in fish population have followed the application of these methods. A fair review of the literature of stream improvement was given by Hubbs, Greeley, and Tarzwell (1932). This work emphasizes that methods which have long been practised in English streams were not necessarily those best suited to streams of a different character in the State of New York, and that what might be appropriate in that State was not necessarily suited to the conditions offering in Michigan. They say that the basic idea is to determine what factors are limiting the abundance of catchable trout and then to proceed to overcome or to remedy the natural deficiencies. The physical requirements they list as sometimes offering scope for remedial action are water temperature, cover, and spawning grounds.

TEMPERATURE

In New Zealand, while water temperatures may drop below or rise above the optimum range for growth of trout, losses directly attributable to high temperature occur rarely and in few waters. The writer has twice found trout which had apparently succumbed to an oxygen deficiency during high water temperature. One case was in a small stagnant pool in the bed of the Hinds River during a local heat wave in February, 1946, when air temperatures exceeded 94 deg. F. There, with an extraordinary concentration of fish and in the presence of much vegetable detritus, 44 per cent. of 41 brown trout and 13 per cent. of 93 char (*S. fontinalis*) had died.

Elsewhere in the same period brown trout in turbulent waters were not visibly affected by water temperatures of up to 78 deg. F. On one occasion temperatures were observed to reach what, under the conditions ruling—prolonged calm weather —proved to be "discomfort level" for brown trout. This was in a shallow lagoon connected with Lake Poerua, in Westland, when, in December, 1934, with the lake temperature at 80 deg. F., trout left the lake and massed densely in the mouth of a small tributary, where the temperature was 56 deg. F. Such conditions may occur irregularly in different parts of the country. In no particular water are they known to occur so frequently as to warrant remedial action by tree-planting to provide shade.

COVER

Cover is an essential environmental need of trout. It may be satisfied by boulders and other obstructions, or by shade-giving banks, or by mere depth of water. Impressions are that there is a correlation between size of trout and depth of water, but the requirement of depth may be less where alternative cover is good. Under New Zealand conditions, cover of the type provided by coarse boulders, undermined banks, fallen sods from banks, branches, and detrital matter is so much used by eels as to suggest that it may have a greater significance to these predators of nocturnal habits than to trout. It would certainly be most unsafe, on present knowledge, to advocate additional cover of this character as a practical measure of stream improvement in this country. It is possible that the removal of existing cover might give better results. At this stage it would seem warranted to contemplate remedying deficiencies of cover only—

(1) As an experimental measure;

(2) In small streams subjected to abnormal angling intensity;

(3) Where the deficiency of cover is overcome by increasing depth of water; or
(4) Where, with the provision of other cover, measures are also taken to control eels.

SPAWNING GROUNDS

Spawning grounds are useful only if accessible. Much attention has been directed to this problem where dams impede access of migrating salmon. The question, however, requires wider consideration.

Especially on the east and south coasts of the South Island, the access of trout from the sea may be barred by shingle barriers in the case of coastal lakes such as Ellesmere and Waituna, and also in rivers such as the Ashburton, Hinds, Opihi, and Kakanui. It is possible that trout seeking to enter these waters in winter, on occasions when access is blocked, would go along the coast to other streams. However, it is not known that they usually do so. Because of the common excessive use of spawning grounds, it is desirable that access should be given to as much spawning ground as possible. It is sometimes practicable to achieve this result for a reasonable cost. In some of these waters, anglers sometimes cut an outlet to permit entry of trout from the sea during the angling season. It would seem at least equally desirable to ensure entry of fish in the spawning season.

Access to useful spawning tributaries, especially of streams with shifting shingle beds, is often impossible because of shallow water at the confluences. Good spawning tributaries at the mouth of the Wairau River, in Marlborough, are often affected in this way. The mouth of Slovens Creek, which enters the Broken River in Canterbury, was, in 1933, too shallow for spawning salmon to enter until it was modified by a few hours' labour, after which salmon were able to enter freely.

An access problem of a similar nature occurs at Lake Acland, in the Ashburton River headwaters. Here the only available spawning ground is an outlet stream down which trout pass to spawn. However, intermittently the level of the lake drops and denies fish access to the spawning grounds. Again, the drop may occur in summer, with loss of young fish in the stream. In such circumstances relief may be afforded by impounding a reserve of water.

Where natural falls prevent access of spawning trout to extensive upper reaches of streams and excessive accumulations of spawners occur below such falls and fish released above migrate downstream while immature, there may be good grounds for providing access. Especially is this so in such a stream as the Whitikau—a Tongariro River tributary—which contains no eels. A slight and inexpensive modification of the fall in the Whitikau would give permanent access to much water which at present becomes available to spawners only when floods occur in the spawning season.

Permeable weirs may prevent dispersal of spawning fish and cause them to concentrate and to become more vulnerable to poaching. A dam on the Kakanui River, at Maheno, is of this type. Sealing its base would ensure a sufficient flow over the top to make it always passable to trout.

Earlier (Hobbs, 1940), attention was directed to the significance of spawning areas in influencing the distribution and abundance of stocks of trout. Stocks have developed until they are using most available spawning grounds, usually to an extent where overlapping of redds and some wastage of eggs occurs.

Is the artificial provision of additional spawning grounds feasible? Earlier in

this paper, reference was made to Waituna Creek, in Southland, where a more rapid flow, followed straightening of the stream, scoured fine detritus off gravels and so increased the extent of spawning areas. Drains cut through low-lying grounds round Lake Ellesmere have served the same purpose. At Inchbonnie, in Westland, the felling of trees into spring creeks and the establishment of watercress in them decreased flow and enabled silt to bury gravels previously used for spawning. Small quantities of gravel spilt into a tributary of the Pourakino River, in Southland, from the ballast of a tramline were used by trout as spawning ground in a length of stream which was deficient in gravel. Such changes in extent of the spawning grounds have been the accidental consequences of other changes.

A remarkable case is that of a mill race in the Kakanui River, in North Otago. As reported elsewhere (Hobbs, 1940; Appendix K), the spawning areas in the lower twenty miles of this river were surveyed in 1936. The number of eggs and alevins in spawning redds was 534,000. The stream had an average width of about 40 ft. If all the redds had been massed in one area they could have fitted into a $54\frac{3}{8}$-yard length of the river. However, all redds were not made in the principal stream. Nearly a third of the total number were in the tail-race of a flourmill. This race had been cut across an elbow of the stream through soft alluvium to a depth sufficient to expose underlying gravels. Redds occupied only a portion of the race, much of which was unsuitable. Yet its construction increased by nearly 50 per cent. the known spawning ground available in twenty miles of river, and, because the volume was regulated by a weir, redds in the race were afforded much better protection from floods than was offering in the open river.

The area of stream-bed in which redds were found in the Kakanui comprised only 0.15 per cent. of the total, and the portions used were widely spread. In the accessible portion of the race below the mill, redds occupied 210 square yards, or 5.25 per cent. of the accessible bed. They held 162,000 eggs. If the whole of the 4,000 square yards of bed below the mill had been suitable for spawning, it could have held about 3,000,000 eggs; such a concentration might be most undesirable. In the Kakanui system, about 75 per cent. of the redds were either superimposed upon or partially overlapped by others. The mean deposition per square yard occupied was about 800 ova. At this rate of deposition, a race 625 yards long and 6 ft. wide would hold 1,000,000 eggs. However, the construction of races which would be wholely occupied by redds is not ideal, for handy dispersal areas in which fry may feed without undue competition are desirable. Earlier, emphasis has been given to the fact that, with excessive concentration of fish, survival is low.

The fact that the extent of spawning ground has often been altered by changes made for other purposes suggests that useful results might follow from the planned extension of spawning grounds. Planning would contemplate obtaining the maximum results for the minimum effort by the selection of places which offered certain natural advantages. These are waters, controllable in volume, which may be diverted across ground of suitable gradient, where good gravel of from one to two inches could be uncovered at shallow depth. The entrance of tributaries through low-lying alluvial flats and elbows of streams upon such flats offer the best possibilities. Because flood waters tend to follow the more direct course, which a spawning race across such a flat would take, a protecting intake weir is

essential. Because, with excessive concentration of stock, survival will be lower, a succession of small races entering separate dispersal areas, or races so designed that spawning ground and dispersal area are interpolated, are preferable.

There are other possibilities of extending existing spawning grounds. Where, in spring creeks and other relatively stable streams flowing over old alluvial gravels, suitable for spawning, and where such streams are unnecessarily deep, increasing the breadth may add appreciably to the area of spawning ground.

Possibly both qualitative and quantitative improvement of the spawning grounds is feasible in other cases. Where large trout spawn in relatively stable streams of slight gradient, such as the outlet stream of Lake Tripp in Canterbury, Waituna Creek and waters of similar type in Southland, steep ridges of gravel are thrown up, separated by silty weed-grown pits. Systematic clearance of weeds, raking and levelling of gravels, and dislodgment of silt with, in some cases, increase of rate of flow by cutting channels across "S" bends should improve both the quality and extent of spawning areas.

The reclamation of good gravel reaches of streams such as the Waikaka, which enters the Matuara, should be feasible. There, persistent precipitation of fine detritus from gold-mining operations (since abandoned) has embedded gravels. At present, the Mataura is so well stocked that this reclamation seems unnecessary, but, with continued increase of exploitation, the need for additional spawning grounds may arise, and the particular stream might be restored to its original condition if its bed were dug over by mechanical means.

Artificial extension of spawning ground is not everywhere desirable, but is worth considering where existing grounds are of insufficient extent to produce enough fish to make efficient use of available food resources. Earlier, it was emphasized that the extent of spawning ground bears no fixed relationship to the extent of food resources and that the relative extents of these environmental essentials vary greatly from stream to stream.

LOSSES OF KELTS

A problem arises in certain South Island rivers up which large numbers of brown trout pass to spawn. Percival (1937) noted that in one year in the Opihi River, in South Canterbury, and more frequently in the Selwyn River, in North Canterbury, substantial quantities of brown trout remained upstream after spawning and suffered a progressive loss of condition and sometimes died, unless a fresh occurred to induce their return to the summer feeding grounds—in the case of the Opihi the sea, and in the case of the Selwyn Lake Ellesmere. This matter is discussed more fully in Appendix C, where it is shown that fish behave similarly in the Eglinton River, above Lake Te Anau. If the occurrence is regular enough in the Eglinton, it might be possible to remedy it by impounding the waters of Lakes Gunn and Fergus for release to cause artificial freshes at appropriate times. Whether it is feasible to impound sufficient water at the top of the permanent region of the lower Selwyn is not known.

Observations made in 1947 on rainbow trout in the Taupo and Rotorua districts suggested that this species shows a similar disinclination to return downstream from spawning grounds while streams remain low and that the period of vulnerability of stocks to poaching in tributaries of lakes and the condition of fish in the

lakes early in the season may be much influenced by the rainfall during the spawning season. In a tributary of Lake Rotomahana, which has a short course through very permeable country, the congestion of kelts was extreme.

EEL ACCESS

Any physical change in a stream may be expected to give rise to biological changes. The economics of stream and lake improvement involve a search for types of change likely to give the maximum result for the minimum expenditure. Obviously, the obtaining of permanent results from a single outlay offers attractions not afforded by a proposition which calls for regular annual outlay. In an earlier paper (Hobbs, 1940), attention was drawn to the fact that swift-flowing water could prove an impassable barrier to eels, and that, although small eels are able to climb vertical wet concrete walls, they cannot surmount certain falls. Observations on the Oraka Stream, near Tirau, suggest that migrating eels are compelled to delay their upstream journey at a point where the stream is usually confined to a cleft through a reef, until the stream rises in spate and the flood waters spill over the surrounding reef. Small modifications, in the form of overhanging sills, might inexpensively convert into impassable barriers certain falls up which eels at present climb.

Opportunity for this type of work is afforded in different parts of the country. A fall in the outlet stream of Lake Hayes, in Central Otago, and another at Avoca, on Slovens Creek draining Lake Hawdon in North Canterbury, are instances where successful modification would effect considerable areas of trout water. All falls accessible to eels should be regarded as imperfect eel-barriers, capable of being made perfect by the expenditure of money. Whether the potential angling value of the waters above any fall is sufficient to warrant the necessary expenditure is a question to be determined in each case. Even falls of considerable width, such as those on the Mataura River, Southland, may prove capable of being modified if access is obtained only via a few short sections of the broad face of the fall. In each case knowledge is needed as to where access is possible at the different levels experienced during the period of the year when the upstream migration takes place.

Dams, including those built for hydro-electric purposes, are sometimes passable to eels. It is reported that when the flow has been sufficiently reduced, small eels have climbed the wet spillway of the great Arapuni Dam. However, where electric power is generated it should often be possible to deny access to eels by the provision of a deterring electric current across points of access. Electric deflectors have been used for different species of fish, but seem especially suitable for use against a species given to climbing. Several extensive water systems may become eel-less as a result of existing hydro-electric dams or might be made so by modifying existing dams or by care being taken in the construction of projected ones. These include the Lake Brunner system and Arnold River above the Kaimata Dam in Westland, the Waitaki River system and lakes above the Kurow Dam in South Canterbury, the Waikato River above the Karapiro Dam, and, later, the extensive river and lake waters of the great Clutha system above the proposed dam site at Coal Creek.

The prevention of access to eels does not, on present knowledge, seem feasible

in rivers of considerable size but of variable flow which lack falls or gorge sections of steep gradient. Control of eels may prove practicable where volume is fairly regular and gradient is considerable. Outlet streams of lakes often offer both these conditions. Given these conditions, it should be possible to employ the knowledge that eels are unable to swim against the current up which trout may pass. This calls for the confining of streams, possibly by weirs with "V"-shaped apertures in them, the height of the weir and the angle of the "V" being such as to ensure a sufficient current at all levels. Where the gradient is great enough, regulation and direction of flow may alone be sufficient. Where the natural fall is less, the impounding of waters behind weirs with overhanging sills may make an effective barrier. In still more sluggish waters, the seasonal trapping of migrants may have to be done.

There is need for additional knowledge as to what are the cheapest and most effective forms of eel-barrier for waters of different type. Among waters well suited to experimental modifications are the outlet streams of certain lakes in the Canterbury and Otago provinces.

GENERAL COMMENT

It is emphasized that over a very long period the bulk of the anglers' licence fees has been spent on work now found to be of a highly speculative character. The various possibilities of modifying physical environments discussed in this section relate to types of project which, while speculative, are justifiable if regarded as experiments and if so planned that the costs and the results obtained may be appraised.

Essentially there is need for appreciation of the paucity of funds which could be used for physical modification of environments and of the fact that, if economic dividends are to be obtained, they will arise from intelligent use of opportunities which different natural features in some places present.

Fishery Protection

POACHING

For many years the protection of stocks of trout during the spawning season has been a grossly neglected duty in many parts of New Zealand. Basically, the reasons for this are—

(1) Local management is in the hands of councils of licence-holders, who in most areas are personally acquainted with conditions only in the angling season.

(2) The enforcement of restraints of angling technique during the angling season often tends to assume an exaggerated importance, because, again, members of councils have more personal acquaintance with breaches of regulations which occur in season than with out-of-season breaches.

(3) The extraordinary preoccupation with the welfare of the few eggs which may be seen in hatcheries has often blinded councillors to the fact that such eggs are usually only an insignificant fraction of the greater number naturally spawned and therefore not observed. (Note: In some districts it has long been the practice to recall employees from field patrol duties and to tie them down to hatchery work at the very time of the year when trout become most vulnerable to poaching.)

(4) The overlapping of the trout-spawning, fish-hatching, game-shooting, and opossum-trapping seasons has thrown on the field officers of Acclimatization Societies a burden of duty often impossible for them to discharge adequately without the provision of seasonal assistance, which is not usually arranged.

(5) The angling members of councils are primarily interested during the season in angling restrictions, and, out of season, in hatchery work, and the shooting members in pre-season shooting breaches. The field officers, who alone are in a position to take a balanced view of the needs of law enforcement, usually occupy so subordinate a status that their views are not sought and are not always well received if offered.

No general systematic attempt has been made by local authorities to learn where and when trout spawn in different waters, although a limited amount of information on these points has sometimes become available incidentally to efforts to locate stocks to strip for hatchery purposes.

The writer has not found it possible to obtain sound official local guidance to major spawning areas in most streams in any one district. In some districts during the last decade, there has been an improvement in the quantity of information available, which possibly reflects the publicity given during this period to the significance of natural reproduction. Over a long period of years, successive field officers have finally left their employment, taking with them the many useful facts arising from their experience which could usefully have been recorded in orderly fashion in the offices of societies. Thus there has been no systematic recording of the basic information on which an enlightened policy of law enforcement could be based.

Such ranging of spawning stocks as has been done has often tended to be highly localized to the vicinity of fish traps. Few such traps are operated; yet in five districts in recent years the staffs responsible for care of the traps and the stripping of fish in them have proved incapable of safeguarding from poachers even the fragmentary parts of the total spawning stocks which enter such traps. They have had to call in field officers responsible for ranging large areas of country, and thus again the preoccupation with hatchery work has tended to lead to the neglect of many other waters.

Often the inability of official organizations to provide information as to where and when trout spawn has compelled the writer to seek information from reputed poachers, who (when the time bar on prosecution for past offences has been explained) are sometimes very frank. Apart from admissions of poachers, evidence seen during surveys of spawning areas in both large and small acclimatization districts has included trails of eggs leading up banks of streams, poaching implements "planted" for future use, and partially-made redds (distinguishable from trial redds) from which fish have been removed.

No general assessment of damage done to stocks by out-of-season poaching is possible. In some areas, little frequented by anglers, stocks are exploited almost wholly by poachers, and exploitation is on a considerable scale. In a few areas, for instance, in the northern portion of the Auckland province, spawning trout cannot be easily poached because of poor access by land to the dispersed spawning places, many of which are in waters of above usual depth. In a great number of streams in New Zealand, spawning trout become highly vulnerable in winter when—

(1) The relative absence of anglers and rangers on streams takes away the main deterrent to poaching; and

(2) Fish, which in summer are widely dispersed in deeper water, forsake the protection afforded by dispersal in deeper water and concentrate in great numbers in relatively shallow waters.

Impressions from examinations of spawning areas in many parts of the country and from discussions with many experienced poachers are that the winter field coverage by law enforcement staffs is so inadequate that, except where riparian owners happen to be anglers, poaching can often be done with impunity. A second impression is that, whilst sporadic destruction of spawning fish may occur anywhere that fish become vulnerable, regular poaching on a large scale tends to be highly localized and that for no readily apparent reason it is "fashionable" in some areas and not in others. Its popularity, however, may be much influenced by the attitude of rural landowners; also a sufficient proportion of anglers resident in country areas is probably a powerful deterrent.

It should be one of the essential first steps of a sane policy of fisheries management to learn where and when trout spawn and to ensure that this knowledge is applied for the well-being of stocks. To recall officers from the field for hatchery duty at the very time when increased vulnerability of stocks should call for redoubled vigilance in the field is not good management. The acquisition of knowledge, which should result from the more adequate patrol of spawning areas, should prove a healthy and needed corrective to past ill-balanced views on the relative significance of artificial and of natural propagation.

FISH SALVAGE

Substantial losses of trout occur in parts of New Zealand in most years through streams drying up, especially in summer time. Streams which are affected most regularly are principally on the eastern side of the South Island. Fewer streams are affected less regularly in the southern portions of the North Island and on the west and south coasts of the South Island.

It is again evidence of the extraordinary preoccupation with hatchery work that only in this last decade, and then only in the case of a very few streams in a very few districts, have a few Acclimatization Societies tried systematically to salvage fish from drought areas. **Some of these same societies from earliest times permitted quantities of fish, of greatly more value than those produced in their hatcheries, to die year after year.** Only in a few districts—notably in North Canterbury and Marlborough—has the problem been tackled at all seriously and the salvaging of fish become a regular feature of management policy. It began in both districts in 1936–7, at about the time that attention was being directed, by research studies, to the importance of natural spawning.

In the Selwyn River, in Canterbury, Spackman (1892) referred to a great loss of trout under drought conditions, and spoke of the stream as disappearing for nearly 20 miles of its length in dry seasons. Although the Selwyn River was for long a major source of supply of hatchery eggs, there is no evidence of regular attempts being made to salvage the naturally produced fish which died there in many years until as late as 1936–7. In that summer, 67,810 brown trout were salvaged. Since then the saving of fish has become a regular feature of the

society's policy. The scale of operations has since varied according to needs, and was modified by transport difficulties in war years. Quantities shifted in different years are variously described as, "ranging from fingerlings to three and four-year-olds," "yearlings and upwards," and "fish of 5 in. to 12 in."

On the basis of data given earlier, the survival value of these fish might be from 100 to 200 times that of unfed hatchery fry. Thus, 67,810 salvaged fish might represent the survival of from between 6,000,000 and 13,000,000 fry. Yet the fish saved were collected and transported for a fraction of the expenditure of time and money which would be required to produce even 1,000,000 hatchery fry.

In Marlborough, where sporadic salvage work had been undertaken earlier, about 120,000 fingerlings, mostly of 3 in. to 4 in. in length, are reported to have been salvaged in 1937. No trout had been released from hatcheries in Marlborough for about 15 years before this. The fish were the product of natural spawning in the Waikakaho and other tributaries of the Wairau River. The regularity with which it has been found possible to save fish since 1937 suggests that there were frequent and severe losses before that time.

The salvage operations mentioned above relate principally to two streams in two districts where more regular attention has lately been given to this necessary work than it has received elsewhere. Fish which could be saved for a small outlay are still permitted to die in too many waters. The efficient management of a district calls for the keeping in district offices of reliable records as to all places where losses occur, with details of dates, frequency and extent of such occurrences, remedial action taken, and difficulties encountered. Now, after up to seventy years of management, a limited amount of specific information on these matters is readily available in two or three district offices.

A second necessity is a system of field patrol, preferably with the organized co-operation of local landholders, so planned as to ensure reasonable notice of threatened loss. The third essential is suitable apparatus and gear for collecting and transporting fish and the knowledge of how this can be done most efficiently.

FISHERIES REGULATIONS

Local fisheries authorities have inclined towards progressively restrictive regulations intended to conserve stocks, particularly during the past ten years. However excellent the intention of such regulations, it is necessary to examine them critically for two reasons. No angler wishes to see his sport hampered by an unnecessary multiplicity of petty restrictions. The purpose of regulations is to conserve stocks for use and not to reserve excessive proportions of them from exploitation.

The major restraints on angling are: (1) Duration of season, (2) minimum legal size, (3) maximum daily bag, (4) selective restrains on lures.

As none of these measures is based on certain knowledge of the results obtained, all must be regarded as precautionary. They may help to maintain stocks and to ensure a better spread among anglers of such fish as are captured. Again, they may reserve from the anglers more fish than are needed to maintain stocks or than streams will support to the best advantage. It is a major aim of fisheries science to endeavour to determine what optimum continuing yield may be taken, and it will be apparent that what is the optimum for one stock under one set of conditions

will not necessarily be the optimum for another stock under different conditions. Yet in designing regulations for a series of waters, several of which may be visited by an angler in one day, it will be probably always necessary to avoid the complexities of law enforcement which would arise from a multiplicity of local regulations and, instead, to legislate only for the most usual conditions.

Duration of Season:

The optimum duration of the close season is not wholly a matter of what is best for the fish. There is little doubt that most anglers tire of their sport towards the end of the open season of seven months, and would find the weather too inclement if it were longer. Moreover, after a closed season, they return to their pastime with renewed enthusiasm.

In general, the open season extends from 1st October until the succeeding 30th April. In high-country lakes, especially those containing rainbow, the season usually opens a month later. Where angling technique is not highly developed and most fish are killed with live bait or artificial minnow during freshes in springtime, there is sometimes a demand for an earlier opening date. Where an earlier opening date has been tried, the experiment has been short-lived, and the anglers themselves have asked for a return to the usual opening date.

Much more widely there is pressure for an earlier closing date, for, as ovaries fill out in the fish in the closing months of the season, anglers become conscious of the quantity of eggs destroyed in the fish they take. The spawning of any considerable number of trout of any species before the end of April is unusual in New Zealand. Unless there are valid reasons for reducing the total quantity of fish killed, there is no justification for closing the season earlier. The ovaries, which may become more conspicuous in autumn, are there in spring and summer also, and destruction of developing eggs is inevitable no matter when the fish are taken. The expectation of successful spawning by a fish which has survived until the last weeks of the angling season is greater than that of the fish at the commencement of the season, but this will be so no matter at what date the season closes.

The experiment of closing certain streams for a season or two to enable stocks to build up has been tried in New Zealand, but as a means of effecting any permanent improvement it is a failure because excessive concentration of angling effort on the deferred opening date quickly reduces the stock to its earlier level.

The permanent closure of nursery streams should not be necessary where sufficient protection can be afforded by restrictions on lures and size-limits. In any case, it should not be contemplated without certain knowledge that a tributary is in fact a nursery area for a larger stream and not the habitat of a local stock of poor growth and small reproductive size.

Minimum Legal Size:

The question of minimum legal size is a greatly more complex one than it at first appears. In view of the trend toward fixing progressively higher size-limits, it is necessary to emphasize that all existing limits are based on the surmise that they are desirable rather than on any certain knowledge. They are essentially precautionary measures.

The assumption, which is basic to the fixing of size-limits, is that the undersized fish which the angler returns to the water will continue to grow, to be

recaptured at a greater size, or to spawn, or both to spawn and later to be recaptured. The assumption is not necessarily correct. Only a proportion, differing under different conditions, will survive to reach legal size or sexual maturity. Of such as do survive, only a proportion, differing according to the intensity of angling, will be encountered successfully a second time by anglers. If fish survive and spawn, they may or may not (according to the intensity of utilization of spawning ground) add to the total of fry produced a quantity sufficient to ensure more than their own replacement. In no one stream is it known for certain that the return of, say, 100 fish of 4 oz. each (25 lb. total weight) will lead to the survival and recapture of even 25 fish of, say, 1 lb. average weight.

In the Horokiwi River, Allen (1945) showed that about 99 per cent. of the fry and about 85 per cent. of the yearlings were lost in a year. In this small and heavily-fished stream, anglers removed only about a twentieth of the total weight of trout flesh produced each year. Percival (1932) recorded impressions of the stock of the Hinds River obtained by netting. The proportions of fish taken were 100 approaching one year, seven approaching two years, and one older fish. These data call for caution in assuming, without clear evidence, that a sufficiently high proportion of under-sized fish will survive and be recaptured at a larger size.

Whether under-sized trout which survive to maturity and escape recapture by anglers will make a useful contribution to the stock by spawning will depend on the conditions offering in the particular stream. Where additional spawning ground is available the contribution should be useful. Where spawning ground is already intensively used, it is possible that other eggs will be dislodged by further fish attempting to make redds and that thus the additional spawning will be of little avail.

There are in New Zealand a number of stocks of both brown and rainbow trout which mature and spawn at very small sizes, and exploitation of some such stocks at a length of 9 in. is permitted.

In the Water of Leith, in Dunedin, which sea-run fish also enter, fish in the 9 in. group comprised approximately 7 per cent. of a sample of 175 fish of a mean length of 13.1 in. taken by anglers. In the Otago Acclimatization District the size-limit was 9 in. in the Leith and in two other small streams, 10 in. in most waters of the district, and 11 in. in the Mataura River. The distribution of a general collection of 2,343 fish killed by anglers is shown in Table XXIII.

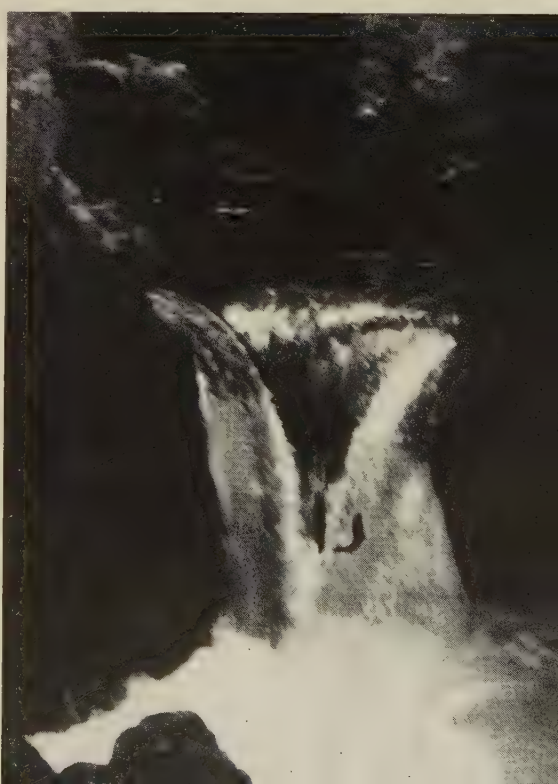
TABLE XXIII

Inch group.	Percentage.	Inch group.	Percentage.
9	0.5	17	6.2
10	8.2	18	7.4
11	10.3	19	4.9
12	12.8	20	3.7
13	10.4	21	3.2
14	12.6	22	1.7
15	7.8	23	1.0
16	8.4	24 and over	0.9

The general size-limit of 10 in. in Otago is lower than in most other districts, where often it is 11 in. and sometimes 12 in. or higher. The raising of the Otago

Tongariro River—Famous rainbow trout river and tributary of Lake Taupo—the largest of the Taupo and Rotorua series of Central North Island rainbow trout waters. The river itself contains no significant number of resident fish. It is a production area for great quantities of young trout and provides moderate angling in early summer and exceptional fishing in autumn for mature fish entering from the lake to spawn. The fishing is greatly conditioned by height of water. With a low river in spring, excessive quantities of kelts are present at the opening of the season. A few fish spawn in all summer months, but appreciable runs do not commence until the autumn or early winter freshes.

The history of the Taupo fishery is remarkable for a second peak in size of trout (an average of over 10 lb.) in 1923–4 some 13 or more years after the peak which followed the introduction of rainbow. Although the second peak is often attributed to reduction of numbers following netting, it is doubted whether quantities taken were significant. The size of trout to-day is slightly above the average since 1930 and appreciably better than in 1915–20. (Plate XXIX.)



Whitikau River—Tributary to the Tongariro River. Rainbow trout of about 5 lb. attempting unsuccessfully to leap a natural fall and obtain access to extensive spawning grounds above. Failure of fish to surmount this obstacle, except in times of flood, causes an excessive concentration of spawners lower down and great wastage of eggs as successive fish root up the same areas of bed. (Plate XXX.)

A tributary of Lake Rotomahana—one of the Rotorua (central North Island) series of rainbow trout lakes. Only some of the 60 to 80 trout of 2–4½ lb. in the pool can be seen. They are spent fish which remained up-stream and suffered a progressive deterioration of condition because no fresh occurred to induce their return to usual feeding grounds in the lake. Just as freshes induce entry into spawning streams, so too they encourage the subsequent return of spent fish. The early season condition of trout in some waters may be much influenced by the presence or absence of floods at suitable times. (Plate XXXI.)

APPENDIX C

Injuries to Trout in Stripping

In Westland in 1934, an endeavour was made to learn what losses of trout resulted from stripping. All fish stripped were marked by fin clipping and released below traps. Of 301 females and a number of males, seven fish, all females, were recovered dead from pools inspected regularly below traps. The fish were stripped by the writer, who was much less experienced than men employed regularly in obtaining eggs for hatcheries. More than usual pressure was used in obtaining eggs. A dozen fish killed for examination showed that the extrusion of ova had been 91.5 per cent. complete, as against 88.6 per cent. at the Selwyn, where the work of the usual operative was checked in the same year. The extrusion of ova from the fish in Westland which died was 94.5 complete. These data thus suggest an outside limit of 2.3 per cent. for losses of mature fish, which is probably not approached under usual conditions.

Where ova are obtained almost wholly from wild stocks, it is difficult to learn whether trout suffer injuries from which they slowly succumb. It is evident from reports (Kendall, 1920—subjoined discussion) that stripping of pond stocks can be carried out without substantial ensuing loss. Stokell (1936 and 1938) believed that heavy losses of trout which took place some miles above the trap-site in the Selwyn River were of fish which, although too incapacitated by stripping to return downstream to their usual feeding grounds in Lake Ellesmere, had got past the trap, below which they were released, or waited until it was removed and have then travelled several miles upstream. He had accepted the views of Armistead (1920) and Titcomb (Kendall, 1920—subjoined discussion) that stripped trout journey upstream and make redds if one or two eggs are left in them. He accepted the erroneous view of Kendall (1920) that ova do not naturally fall into the abdominal cavity and could not be extruded if displaced into it. He inferred that eggs found there in dead fish in the Selwyn had been displaced by handling at the trap.

The reaches of the Selwyn where heavy losses occurred are ones in which fish, which are not stripped, have access before the trap is installed and to which further fish have access after the trap is removed. Fish comprising the fraction of the run that is stripped were released below the trap, but could have gained access to these reaches after its removal.

Observations in New Zealand are entirely contrary to those of Armistead and Titcomb on the behaviour of stripped fish. Percival (1937) quotes Mr. J. Digby, who was in charge of the Selwyn trap for 14 years, as saying that of stripped females released below, only an occasional one returns to the trap, except when stripping is carried out on a rising river, when up to 10 per cent. might return within a few hours. The river did not rise in the period in question in 1932 and 1933. In Appendix B it was shown that in Westland in 1934, stripped fish released above a trap would not journey up beyond the nearest pool offering cover. There is thus nothing to suggest that any quantity of stripped fish would have sought to swim up the Selwyn to the areas where losses occurred. The reported differences of behaviour of trout after being stripped possibly arise from differences in the quantity of eggs left in fish in New Zealand and abroad.

The presence of eggs loose in the abdominal cavity of matured brown trout is usual, whether such fish have spawned naturally or have been stripped. Stokell reported eggs ranging in number from nine to 146 in 18 fish from the area above the Selwyn trap. Twelve trout killed by the writer at the Selwyn trap in 1934 after they had been stripped by the usual operator contained eggs, nearly all loose, ranging from 90 to 325—mean, 193. Only four contained fewer than the maximum found by Stokell in fish he assumed had been stripped. In Westland in 1934, ten smaller fish, killed after being stripped, contained from 28 to 190—mean, 93. In 1941, when no trout were stripped at the Selwyn, nine of ten kelts killed contained loose eggs ranging from two to 113—mean, 19. Of these fish, five also contained deflated residual eggs from earlier years. In 1934 in Westland, 14 small brown trout which had never been stripped,

in that or any other year, were captured as they returned down from spawning areas. Of them, 13 contained loose eggs, which ranged from one to 23. Percival (1937) has shown that displacement of ripe ova into the abdominal cavity is a usual and natural process in brown trout in New Zealand.

The failure of brown trout kelts to return downstream, with consequent loss of condition and sometimes death, as observed by Stokell in the Selwyn in 1932 and 1933, is usual in New Zealand when freshes do not take place. In 1932, freshes did not occur until October, when surviving fish immediately disappeared from upstream areas. The following year, in the absence of floods in winter, spring and summer, most fish finally died or were captured by anglers. In 1941, no trout were stripped in the Selwyn. For observational purposes, a trap was installed on 6th June and was maintained until carried away by a flood on 14th August. Approximately 28,000 trout passed upstream before 6th June. By 20th July, only 200 kelts had returned downstream. By the end of July, losses of fish were taking place at the upper limit of the accessible water, when 25 dead were counted in 440 yards of river. Farther down, where the concentration of fish was less, dead observed averaged about two per mile. By 13th August, 102 dead kelts had drifted down to the trap, but the number of live returning kelts had risen only to 544.

The following day, the first flood of the season occurred, and in a few hours, as the waters rose, 2,348 kelts were counted and great numbers of additional fish were seen before the trap was carried away. This disinclination of kelts to return to their usual feeding grounds without the stimulus of a flood is not peculiar to the Selwyn. It was observed by the writer in tributaries of the Bruce Stream in Westland in 1934 and in the Eglinton River in Southland in 1937. Percival (1937) reported like behaviour on the part of trout in the Opihi River in South Canterbury.

Such behaviour is not peculiar to brown trout. A substantial accumulation of rainbow kelts was noticed in a small tributary of Lake Rotomahana (Rotorua district) in September, 1947. The stream had not flooded for some months. Further, the quality of rainbow trout taken in November from the Tongariro River varies much from season to season according as or not floods have induced kelts to return to Lake Taupo.

APPENDIX D

Claims of Success of Hatchery Operations

Apart from indisputable evidence as to the useful part hatcheries played in the original liberations of trout in New Zealand and equally clear evidence that stocks in certain lakes have been maintained by periodical releases of fish sometimes produced in hatcheries, claims of the value of hatchery operations in New Zealand are more easy to find than evidence to support them. A perusal of successive annual reports of many administrative bodies discloses a marked tendency to prophesy improved angling at an ever-receding "near future," as a result of liberations made. This "horizon-chasing" often continues over periods of years until either the subject is just quietly dropped or the wheel of fortune rewards its persistent backers. Knowledge of the periodic fluctuation of populations, be they of fish, birds, mammals, or insects, indicates that he who prophesies persistently enough an increase of population will sooner or later be right—just as right, in fact, as he who prophesies the reverse.

Man is somewhat over-inclined to take credit for the occurrence of natural phenomena and also to observe only what his anticipations lead him to expect. In the Auckland Acclimatization District the opening of a hatchery of increased capacity in 1935 led to optimism among anglers as to improved fishing in the lower waters of the Waikato River. Rises of fish were observed where none had looked for rises before. A few under-sized fish captured were regarded as hatchery products, and success seemed only a season or so distant—and then the vision of the future faded as time elapsed without fruition of anticipations.

On a stream in that district the writer was accosted by a riparian owner, who pointed to the numerous yearlings present in the stream as evidence of the great advantages fingerlings had over smaller fry. He stated that in years of residence he had never seen results like these, until shortly before, when fish of the larger size were released. Careful inquiry showed conclusively that actually only fry of the usual size and number had been released there. The farmer had placed his own interpretation on a somewhat vaguely worded newspaper statement of proposed liberations. Later, he heard that fish had been released. He looked for and found what he expected to find. He would probably have been able to see plenty of fish of like size there in any earlier year had he looked. Incidentally, he might have observed that the stream has exceptionally fine spawning grounds which are used most successfully by many large fish.

In addition to occasions where evidence is lacking that any observable increase followed intensification of stocking, or where improved fishing may have resulted from either improved natural conditions—for instance, absence of big floods—and from a long period of weather suited to the efficient exercise of locally popular angling technique, two more serious cases require notice. The first is simply a case where an author of certain conclusions, reached incidentally to another study, states that data now available render untenable conclusions suggested earlier by more meagre data. Professor E. Percival, in his study of the effects of increased angling intensity, more especially on the stock of the trout in the Oreti River in Southland, accepted the then prevalent belief that stocking was on a significant scale (Percival, 1932). In a personal communication, he requests publication of the statement that he considers the changes in composition of stock observed in the Oreti and elsewhere, shortly following increased stocking, cannot, on further examination, be ascribed with any certainty to that cause.

The other case requires notice because in one district much publicity has persistently been given to views held locally as to the efficiency of maintenance liberations, and antagonism to new knowledge has resulted in a partial presentation of a case which has hitherto been ignored. The facts are that the South Canterbury Acclimatization Society did not operate a hatchery regulary until 1922–3, when temporary installations were made, to be followed in 1926–7 by a permanent structure of increased capacity. Sporadic releases of fish were made

from 1901–02 to 1922–3, amounting in one year to 100,000 fry, but for the balance of the period the mean annual release of fry does not appear to have exceeded 10,000 fry. From 1922–3 to 1926–7, the annual releases were about 160,000. Thereafter they increased to a mean of about 730,000 from 1926–7 to 1935–6. Licence revenue rose from about £390 per annum at the beginning of the century to about £510 in 1908, and thereafter fluctuated between £520 and £580 until 1923, when it stood at the lower figure. Thereafter it increased very strikingly to £890 in 1929 and £925 in 1932. (Revenue figures are approximate means for three-year periods centered on the years given.)

Locally, the increase in revenue is put forward as evidence of the benefits of hatchery work. Inquiry of anglers in South Canterbury discloses a fairly widely-held belief that fishing was very poor from about 1917–23, and many anglers, but not all, believe it has improved since hatchery operations were undertaken. Beyond question, a striking increase in sales of licences did succeed the inauguration of a stocking policy in South Canterbury. The inclination to attribute increased sales of licences to improved fishing resulting from more intensive stocking is as understandable as it is unwarranted when all the facts are taken into account.

Reference to reports of the three other large societies on the east coast of the South Island—North Canterbury, Otago, and Southland—disclosed a general long-term tendency for sale of licences to increase. The increase has never been at a steady rate, and the general upward trend is sometimes broken by short declines. The increase of 92 per cent. in licence revenue in South Canterbury between 1920 and 1930 is substantial. However, in the same period the revenue from fishing licences increased by 88 per cent. in North Canterbury, by 65 per cent. in Otago, and by 77 per cent. in Southland. These three societies had been stocking regularly since long before 1920.

Lack of dependence of revenue on rate of stocking is shown by earlier data from North Canterbury. In this district, revenue fell from a mean of £886 per annum for the years 1909, 1910, 1911 to £696 for the years 1919, 1920, 1921. Yet the rate of stocking with brown trout, which in both periods provided the bulk of the angling, increased from about 113,000 fish per annum in the five years preceding 1910 to 574,000 per annum in the five years preceding 1920. In both periods the bulk of the fish were released as fry; in both, much the same number of yearlings were released.

The Marlborough Acclimatization District is also on the east coast of the South Island. From 1931 to 1937, its revenue from fishing licences ranged between £30 and £46; but in 1940 it rose strikingly to £125. No hatchery was employed for trout eggs in the district. From about 1934 onwards, quantities of naturally-bred fingerlings (in a peak year, 120,000 of them) were transferred from portions of a drought-stricken tributary of the Wairau. The fish transferred represent only some of those naturally produced in one of many small streams. A very efficient ranger was engaged, and from then on the district was well patrolled. It is questioned whether any great increase of stock resulted from the salvaging of fish, or the more adequate patrolling of the territory. But much local publicity attended both the salvaging of fish and increased ranging activity.

Publicity given to fisheries activity, of kinds in which anglers have faith, will sell licences. To deny this would be to deny that advertising sells goods. Activity independently reported in newspapers is powerful propaganda. I am reminded of the comment of a South Island hatchery manager who produced great quantities of fry. It was that he did not know whether hatcheries increased stocks, but they certainly increased revenue.

In view of the foregoing facts, it is unsafe to ascribe increased sales of licences in South Canterbury to increased stocking. Actually, a considerable number of factors could have been responsible. These are:—

(1) Those factors which in most districts lead to increased sales—namely (a) growth of population, (b) reduction of the hours of labour, (c) improvement of economic conditions, and (d) improved access and means of transportation to fishing waters. (Note.—The influences of the first and the last of these four factors are discussed in some detail by Percival (1932) in relation to the Southland district.)

(2) Natural fluctuation in the density of stocks.

(3) Cessation in 1917 of the collection by the Marine Dapartment, for sale elsewhere, of the eggs of brown trout in the principal South Canterbury trout stream—the Opihi and its tributary, the Temuka. From 1907 onwards, quantities of approaching 1,000,000 eggs a year were removed, and it does not appear, from available reports, that the total return of fry in all years to streams of the South Canterbury district amounted to more than 100,000.

(4) The substitution by the South Canterbury Society from 1922 onwards of a policy of raiding local wild stocks to obtain eggs only for hatching and local distribution of products.

(5) The engagement in 1921–2 as ranger and hatchery curator of "Scotty" Main—a man of striking personality, who, in his day, was the best known and one of the most efficient of all acclimatization societies' employees.

(6) The provision of a second fine game fish in the rainbow trout. This was in Lake Alexandrina, a somewhat remote piece of water which only became easily accessible to large numbers of anglers during this period. The society's report of 1920 speaks of the lake as being fished by an increasing number of anglers each year and as promising to become one of the society's best assets. These fish were taken on the general licence.

(7) Quinnat salmon, which had spread to South Canterbury waters by natural dispersal earlier, increased by natural propagation strikingly during this period. Their taking, too, was permitted without special licence. Here are some extracts from reports of the local society in 1920: "There has again been no run of salmon in the Rangitata"—the principal salmon river; in 1922: "The run of salmon . . . the best on record . . . several very good catches recorded"; in 1923: "The run of salmon . . . has easily eclipsed any former year"; in 1924: "Decided to discontinue the issue of half-season licences. . . . Salmon fishing . . . available at the end of the season has justified this step being taken." Anglers who had previously taken out lower-priced short-term general licences, principally for salmon fishing, now had to pay the full fee.

It is clear that the increase in licence revenue in South Canterbury was largely paralleled in other districts irrespective of change in stocking policy. It is further clear that in South Canterbury a series of factors could have contributed to increased sales.

APPENDIX E

Change in Size of Trout in the Hutt River

The Hutt River is not to-day—and appears never to have been—a first-class trout stream. It is important only as the nearest river to Wellington which offers trout fishing. Somewhat fragmentary evidence of the angling history of the Hutt River shows unusual features. The evidence suggests that a more extensive change in size of fish may have taken place in the Hutt than in any other stream considered here, and that this change took place in a remarkably short space of time. Although the evidence as to size is often based on small samples, it seems wiser to put it on record than to dismiss certain peculiarities as attributable to the exigencies of sampling.

The earliest recorded releases of brown trout in the Hutt system were: October, 1876, 400; December, 1881, 600; March and November, 1882, 5,300; April, 1883, 2,500; 1884, 10,370; 1885, 24,050.

In the winters of 1884 and 1885, a few large fish were observed moving upstream to spawn.

The first angling season was in the summer of 1885–6. In that and the following season, successful anglers took on unspecified lures 130 trout of the high average weight of 6.76 lb. The number of fish in eight (presumed seasonal) records available varied from eight to 26 and the average weight shown by different records varied from 5.34 lb. to 9.22 lb. The heaviest individual was 13 lb. There is evidence that at this time, trout, in addition to being distributed over a considerable part of the readily accessible waters, were present in the short tidal reaches, and that sea-run fish were being netted illegally at the mouth.

In 1890, the fishing was reported as "fairly good."

In 1893, the river was stated to be "full of fish, but they are mostly small and not in as good condition as in other rivers, the largest fish forsaking its waters during the greater part of the year for the abundant food to be found in Wellington Harbour." Reference is also made to nets impeding the entrance of large trout from the sea.

This is the early history as given in contemporary reports of the local Acclimatization Society. The irregularity of the comments and the absence of data on catches after 1886–7 is regrettable. Additional evidence now available suggests that at no time subsequent to the season 1886–7 did average size of fish taken with minnow or with fly exceed 2 lb. until after 1930. These records, produced in Table IV, begin with the season 1887–8, and confirm the contemporaneous statement that fish were small by 1893, and suggest that this change from large fish to small fish was taking place several seasons earlier. The samples which indicate this are very small, but it is emphasized that each of eight samples which, in the first two seasons, showed an average size of 5.34 lb. or better, was small, the numbers of fish ranging from nine to 26.

Before the Hutt was opened to angling, the licence revenue from other waters—probably mainly the Wainui-o-mata—was about £40. In 1885–6, when the Hutt was first opened to angling, revenue from that portion of the district which includes it and the Wainui-o-mata was about £48. It rose to £50 the next season, and was in the next succeeding seasons £68, £80, £97, £111, £125. There is no evidence of a sharp rise following the catching of large fish in the Hutt. Although these fish were large, the number taken—16 per angler among the successful anglers—suggests a fairly sparse stock at that time.

It would appear that between 1876 and 1885 a number of trout, unmolested by nets or anglers, had been able to grow to a large size in the Hutt. Thereafter the selective effect of nets at the mouth and selective angling (probably with minnow) farther upstream removed a proportion of the large fish, and the presence of smaller fish became more apparent. The total fishing effort directed against the stock at that time could scarcely have had this effect unless the numbers of large trout then present were small. There is no reason to suppose that, within ten years from the first releases being made, the stock must have reached its

maximum density. It is possible also, as the contemporary report suggests, that, as numbers increased, fewer of the larger fish remained in fresh-water after spawning.

The claim that the river had become "full of fish—mostly small" by 1893 suggests that numbers increased after 1885–6. Records of 34 excursions made by four anglers in the Hutt in the eighteen-nineties show an average daily catch of 2.9 fish of an aggregate weight of 2.7 lb. This result is poor, even by present-day standards for other waters which have been considered. Records are available from one angler who fished the Hutt mainly with artificial fly, but sometimes with minnow, between 1887 and 1916. For 38 days between 1887 and 1890, he averaged 1.6 fish per day and the daily catch weighed 1.5 lb. For the periods 1890 to 1900, 1900 to 1910, and 1910 to 1916 respectively, the figures for excursions and numbers and weights per day are: 20 days, 1.6 fish, 1.7 lb.; 124 days, 0.5 fish, 1 lb.; and 55 days, 0.6 fish, weighing 0.8 lb. These data afford no evidence that the trout were ever in great abundance in the Hutt. They show a substantial reduction of the catch of the individual angler after the turn of the century.

larger ones. However, larger societies have often been averse to taking over districts which are not financially self-supporting.

Interdependence and co-operation could usefully replace excessive independence and could lead to a reduction of such anomalies as great contrasts in financial strength, non-uniform enforcement of a law from district to district, and unnecessary differences of regulations and of general policy. No adequate provision has existed for societies to consult and learn from the experiences of one another. Often they have been unable to learn from their own experiences because observations of results of practices adopted have rarely been made and recorded, and generally their annual reports have been very inadequate factual statements.

The need for better co-ordination of activities of the many semi-independent local organizations themselves and also of them and the central administration, and, further, the need for bringing local administrative policy into line with the results accruing from research led officers of the Marine Department to recommend the establishment of an advisory body comprising representatives of central and local administrations and of science. This recommendation, rather than one from Acclimatization Societies relating solely to the control of fisheries research, was put into effect by the Government when, in 1946, it established the Fresh-water Fisheries Advisory Council. At the same time, the Government decided to establish a special administrative service with the duties of supervising local administration and giving direction in the framing of local programmes of practical management in accordance with knowledge arising from research. This involves the provision of an advisory or knowledge-applying service, additional to the knowledge-producing or research service which the Government at the same time increased.

A liaison body has been established which may prove valuable if there is sufficient appreciation on the part of the organizations represented that they are but parts of a general administrative system which should aim at serving anglers and the public interest and that the giving of a uniformly good national service is of greater importance than is the maintenance of any component part of the national organization in other than a satisfactorily efficient form. Basic deficiencies, which at present make impossible the giving of a service of fairly uniform efficiency, include the following:—

(1) The differences in the quality of angling water in different districts reflects, substantially, differences in natural conditions, and are such that the greatest amount of revenue per unit area becomes available where there is least need to spend money on the maintenance and development of fisheries. On the other hand, least money becomes available where it is most needed. It is somewhat anomalous that a right to fish through most parts of the country is conferred by the general licence issuable in most districts; yet the funds arising from sales of licences must be spent where collected. Under existing regulations, funds must also be spent for stated fisheries purposes; yet in practice fees pass into a general account with game revenue, and it is not easy to determine from published reports whether fisheries expenditure balances income. As no time limit is provided for expenditure, indefinite accumulation of funds is possible.

(2) There is so great a difference in the size of districts and quantity of angling water in them that some small far northern ones produce no angling

revenue at all, while some large districts produce so much that considerable accumulations of funds occur. There are many small districts which have a continual struggle to make financial ends meet and which are unable to offer continuity of employment to a field staff and which are therefore much dependent on voluntary services with some casual inexperienced paid help. These smaller districts offer advantages in the greater personal familiarity of council members both with their territories and with angling opinion. Such advantages are only partially met in the largest districts by appointment of delegates from country centres, because regular attendance at meetings by voluntary delegates from considerable distances is not practicable.

(3) The present divisions of territory are largely a survival from the pioneering era and do not represent a logical division to secure efficient and balanced administration purposely made with regard to the present distribution of population, roading systems, means of transport, and availability of revenue.

(4) There was for long an inadequate liaison between the two Government Departments responsible for the central administration of fish and game, and an inadequate regard for the fact that the same local administrative bodies and the same law-enforcement officers were responsible for both fish and game. Arbitrary action by either Department in forbidding an open season might give rise to considerable difficulty. For instance, in the case of societies without reserve funds, lack of game revenue might compel them to carry on solely with angling revenue and so give rise to breaches of the law if such revenue were not employed wholely for fisheries purposes. Efficient central administration demands a continuation of the recently established close relationship between both Departments and regular consultations on all matters which affect the status and efficiency of the local administrations.

(5) The other outstanding basic deficiency is of knowledge necessary to manage intelligently angling waters and their stocks. Knowledge has arisen, and much more will arise, from scientific researches developed from the scheme initiated by Acclimatization Societies. Much more knowledge may arise from the intelligent use of opportunities for its acquisition which are already available to all societies. They could avail themselves of present opportunities by the observation, measurement, and systematic recording of the effects of experimental management policies. This will only become possible if there is a general realization of the paucity of precise knowledge and if it is appreciated that there is no definite answer yet, in regard to any one water, as to how money may be most profitably spent.

These deficiencies are not beyond remedy. If they are overcome and if a willingness is shown to co-operate and to benefit from experience, it should become possible to have an improved system of national and local administration, giving a better service to anglers. Major changes could arise from—

(1) Reconsideration of how the country as a whole could best be split into administrative districts.

(2) Consideration of how fisheries revenue as a whole could be used most

equitably to obtain a more balanced administration and consideration of what matters should be reserved to the Crown to finance.

(3) Consideration of differences in local administrative outlook and practice and the selection, further improvement and general adoption of the best features which have been developed in different districts.

(4) Use of the Fresh-water Fisheries Advisory Council to bring about a better co-operative spirit and to give guidance by the formulation of a broad general policy for all districts in harmony with modern needs and modern knowledge.

(5) Consideration of the need for giving fisheries workers better fundamental training, wider field experience, and increased security of employment on work offering greater intellectual appeal and promise of ultimate advancement.

(6) Employment of better-trained staffs for factual reporting as a basis to the formulation of improved local policies.

(7) Consideration of the high importance of sound objective factual recording in official reports and appreciation of the responsibility for educating anglers by keeping them informed as to the facts on which policy is based.

SUMMARY OF PART IV

As a preface to a summary of the recent consideration of the future course which the management and development of fisheries might take, a few points, which follow from evidence reviewed in earlier sections, may be reiterated. These are:—

Such evidence as there is indicates that, although the average size of fish is now sometimes less, the gross yield of certain long-established fisheries has continued to increase, and there is no evidence that abstractions have yet reached the point where the continuance of a yield, at the highest level yet attained, is threatened.

The demand for angling has for long grown and has been partially met by the exploitation of more remote waters and of some previously under-exploited more accessible stocks. However, in some waters increased angling has already compelled a degree of sharing of the gross yield from long-exploited stocks, and, in consequence, has often lessened the catch of the individual.

Reduced average size of fish in some waters and reduced catches of individual anglers, as the number of anglers has increased, do not necessarily indicate any fundamental unsoundness of stocks or deterioration in the capacity of environments to continue producing trout.

The abundance of trout in different waters to-day reflects, with few exceptions, the suitability of environments for the natural propagation and development of stocks rather than man's attempts to maintain them by releasing artificially propagated fish. Conversely, the paucity of trout in some parts and elsewhere their absence from waters where they have in the past been released commonly reflect environmental deficiencies.

The major concern for the future must be to employ limited funds and powers to ensure that the inevitable increase in the demand for angling

may be satisfied without reduction of the reproductive capacity of stocks and with least reduction of the catch of the individual angler.

In general, the resources available to fisheries interests are too meagre to overcome one of the commonest environmental deficiencies in this country—namely, lack of stability in stream-beds. In general, also, they are too meagre to correct the natural and unequal distribution of trout by making possible the transfer of fish in sufficient quantities from areas where they are abundant to areas where food is plentiful but conditions for successful spawning are wanting.

Very generally in the past, artificial propagation has assumed an importance out of all proportion to any useful function it has fulfilled, or could be made to fulfil, as a means of maintaining stocks in the face of increasing exploitation.

Policy has commonly suffered from a very serious want of balance. What should have been the priority measures of intelligent conservation—namely, protection of spawning fish from poachers and the preventing of avoidable destruction in drought-stricken areas — have too often been neglected. Again, there has been almost an entire neglect of experimental measures so planned that the nature of any results could be learned.

Regulations in restraint of angling have tended to increase in severity, always with the excellent purpose of conserving stocks, but usually with unknown results and possibly, sometimes, with the effect of reserving from exploitation fish which could be removed without harm to the future of stocks. There is now evidence that certain of the conservational restrictions, such as bag limits, have had no significant effect, while size limits may have had an appreciable effect only in some waters.

Local-fisheries administrative bodies, with present over-rigid territorial divisions, great inequality in strength and in practices, and sometimes, with excessively parochial outlooks, are not well designed to cope with future needs. With advantage to anglers generally, there could be changes which would ensure the retention and general adoption of the best features which have been developed in different districts, a reduction of existing inequalities, and closer co-operation as between components of a national administrative system.

If fisheries management is to be put on a sound basis and is to ensure that all that is reasonably practicable is done for the maintenance and development of fisheries, then, in addition to changes in the administrative machinery, there are other important needs. The first of these is for a modest appreciation of the limited extent of present knowledge. The second is for a realization of the meagre extent of the resources and powers with which man seeks to maintain or modify stocks. Thirdly, there is need for the abandonment of measures based on assumptions and their replacement in part by measures warranted by existing knowledge, and, in part, experimentally, by those provisional measures indicated as most promising by such evidence as is available.

Conservation, in its best sense, means such management as makes possible the highest continuing rate of exploitation. There is a danger of a defeatist

or negative interpretation being placed on this term, and of the word being used to justify such inefficient management as contemplates nothing more than progressive increase of restrictive regulations and progressive increase in licence fees, to be spent on measures which offer as little hope for the future as they have in the past.

While at present there is no evidence that reduced exploitation of stocks generally is necessary, it is desirable to consider means of obviating the reduction of opportunity for sport of the individual, which must arise if the past progressive increase in number of anglers continues. Because any increased demand must be satisfied from environments limited in ultimate productive capacity, younger anglers should be encouraged to regard angling as a pastime in which a "skill" incentive will yield more adequate rewards than a "kill" incentive will.

In addition to changes in the administrative machinery, which are desirable to give a better service, and in general outlook of those responsible for future management and exploitation, the interests of anglers would be better served in future if priority were given to three measures which must be basic to the intelligent utilization of fisheries.

These are:—

(1) Adequate protection of spawning fish.

(2) Prevention of loss of fish in drought-stricken areas.

(3) So regulating lawful exploitation that sufficient fish survive to make the maximum efficient use of spawning grounds.

If, when these matters have received adequate attention, additional resources and energies are available, attention might usefully be given to the matters which follow.

There is scope for the development of new fisheries for species other than trout in the northern portion of the North Island, and possibly in one area of the South Island.

In a limited number of lake waters, where conditions favour survival exceptionally, there are prospects of obtaining an economic return from continued releases of trout.

Both in the establishment of new species of fish and in the maintenance of certain existing trout fisheries, there will be need for artificial stocking, in some cases with artificially propagated fish. This will call for the continued operation of a very few regional hatcheries to provide fish where it is known they will prove useful, in place of the earlier system where many hatcheries operated to ensure the broadcast dispersal of fish on the assumption that they were everywhere necessary and beneficial.

In general, additions of competitive species of game fishes to environments where existing stocks develop to a useful abundance cannot be advised. However, in certain waters, the brown trout, in the abundance to which it develops naturally, fails to provide useful fishing, and there is ground for examination of the question of whether it might not be replaced or supplemented by some more easily caught species.

In the present absence of clear evidence of any general deficiency of food for trout, the question of introducing additional fish foods should

be deferred. However, possibilities of introducing useful food animals which would not compete with existing useful forms seem limited. It is possible that, with further knowledge, a need for more food in certain waters may become apparent, and that, with careful study, a restricted range of forms, useful in certain types of water, may be found.

Control of black shags in inland waters of the South Island offers a means of saving quantities of trout very appreciable in relation to past hatchery production, and appearing to be appreciable in relation to total angling catch. The position of the black shag in the North Island is less adequately known, and there is doubt as to the influence of the white-throated shag on fisheries in the North Island, where alone it is abundant.

The abundance, size, and feeding habits of long-finned eels are such as to suggest that a major improvement in trout fisheries might result from their control. Available evidence, however, is insufficient to show what degree of control may be desirable or economically practicable. The control of these fish should be a major measure of future experimental policy.

Within undetermined, but probably narrow, limits, the better control of pollution offers scope for improving environments, but for this purpose improved legislation and administration are necessary.

While modification of physical environments is not feasible on a general scale from fisheries revenue, there is scope for experimental modification for particular purposes, where natural features lend themselves to easy alterations, which might make practicable the securing of a lasting advantage from moderate non-continuing expenditure.

Positive conservation should aim at making more fishing available, not by methods which have proved useless, but by the acquisition of knowledge and the development of improved methods. Progress would be better assured if the responsibility for achieving it were shared by all, and all co-operated actively to secure this desirable end, on such extremely important matters as—

(1) The necessity or otherwise of present regulations.

(2) How regulations could best be framed to ensure the highest continuing yield to anglers.

(3) The feasibility and economic soundness of controlling predators.

(4) The results of any experimental modifications of policy.

The rate at which essential knowledge will emerge will depend greatly upon the amount of co-operation afforded to science by the administration, by angling clubs, and especially by individual anglers. The administration alone can modify regulations and make large-scale field experiments. Anglers alone can supply (in the form of diary records) the best evidence of the present and future status of stocks and of the effects of any experimental modifications of policy. Co-operation in the planning of such experimental measures and the objective assessment of the resultant data are matters for the fisheries biologists, additional to much other work falling within their specialized province.

A continuation of the policy of the last fifty years, with greatly excessive dependence on hatcheries and consequent wastage of much of the money

paid in licence fees, can lead only to an aggravation of the dissatisfaction with angling conditions which prompted Acclimatization Societies to initiate fresh-water fisheries research in New Zealand. On the other hand, by basing policy on sound knowledge, where knowledge is sufficient, and by testing and checking along lines which appear most promising, where knowledge is less adequate, the future can offer assurance of more rational use of resources and powers, and a real hope of achieving the highest continuing yield from environments with the minimum reliance on restrictions to achieve that purpose.

As councils of Acclimatization Societies are elected bodies and must of necessity frame policies substantially along lines which have the confidence of anglers, the future course of fisheries management is largely in the anglers' hands. It is for them to say whether or not measures which have proved incapable of making fishing better and which cannot possibly provide generally for the needs of additional numbers of anglers shall continue to dominate policy; or whether there shall be good team-work between administration, science, angling clubs, and individual anglers in the progressive development of a better balanced and more promising policy.

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APPENDIX A

The 1941 Census of the Selwyn River Run

At the Selwyn River in North Canterbury in 1941 an attempt was made to ascertain the number of brown trout comprising the spawning run and the quantity of eggs produced by them. The attempt was made after many trout had gone up beyond the proposed trap-site. This was at the lowest point at which depth of water made it practicable to work—a point four and a half miles above Lake Ellesmere and about eight miles below where the permanent flow of the river began at the lower end of some miles of dry river bed. The position selected was shortly below where traps had been installed in most years since 1900 to obtain ova for hatcheries.

A trap and high protective rack were installed on 6th June and were maintained until 14th August. No fish were stripped. The sex and numbers of all fish entering the trap were recorded before they were allowed to swim farther upstream, and, at weekly intervals, samples of fish were measured. The rear half of the adipose fin of each fish handled was removed by a verticle cut before the fish was freed. A runway ran from beside the pound up to a small movable panel in the timbered barrier above. Netting extended from each bank down to this panel from upstream and continued through to a second pound to trap kelts returning downstream. A door was so placed that it could close the top of the race or the entrance to the second pound as required. The erection and maintenance of traps and the handling of fish and recording of relevant data were carried out well by Mr. F. David, of the Acclimatization Society's staff.

The counting and marking of up-running fish proceeded steadily from 6th June until 20th July, by which time more than 10,000 marked fish had been released up, and only about 200 kelts (marked or unmarked) had returned down. It was known that very many fish had gone up before the trap was installed, and that small numbers had been spawning as early as mid-April. It became apparent that spent fish were distributed throughout the accessible water above the trap and that they were disinclined to return down while the river remained at normal level. Netting was therefore done in portions of the river between the trap and the upper limit of permanent water at Boyles Ford at various times from 21st July until 5th August. The purpose was to determine the ratio of the known number of marked fish in this area to the unknown number of mature unmarked fish. This was an application of a method employed by Dahl (1918) in Norwegian lakes many years earlier.

The continued movements of fish in lessening numbers up into the area above the trap and of much smaller numbers of kelts down through the trap, after the completion of netting, involved quantities too small in relation to the total present to call for any substantial modification of the ratios ascertained by netting. It was found that as far us as Boyles Ford kelts and ripe fish had accumulated in very great numbers, more especially in certain deeper pools. As late as the beginning of August, the shoals included a small proportion of large ripe unmarked males and females, which must have been up the river from at least as early as 6th June. No difference could be noticed in the proportion of marked to unmarked fish in the deeper pools as against the proportion in the shallows.

Lest proportionately more of the later running fish—marked ones—should have accumulated in shallows, the practice was adopted of netting both deeper pools and shallower reaches where some fish occupied redds. From three areas sampled—(1) Coes Ford to Chamberlains Ford, (2) Chamberlains Ford to Boyles Ford, and (3) vicinity of Boyles Ford—951 fish were examined. These showed, at the respective stations, ratios of marked to unmarked fish of 1 : 1.93, 1 : 2.08, and 1 : 2.40. The ratio of marked to unmarked males, based on the sum of captures at all stations, was 1 : 1.61; for females the ratio was 1 : 2.02.

On the ninth day after the completion of netting, 14th August, the river came down in heavy flood, and with the rising waters came the kelts in great quantity. Of the horde that

came down, some 2,348 were caught and examined before flood waters passed over the traps and rack and gave the remainder an uninterrupted run down to the lake. This small portion of the total handled in a few hours was more than four times as many as had come down in the preceding nine weeks. The fish taken on 14th August, with other returning kelts taken earlier, showed a ratio of 1 marked to 2.5 unmarked. The ratio of marked males to unmarked was 1 : 3.88 and of marked females to unmarked 1 : 2.06. The upstream movement of fish had practically ceased before the flood. Fish marked totalled 2,509 males and 9,921 females.

The total number of fish involved in the run is estimated in the case of each sex from the mean of the ratio of fish netted upstream and of kelts trapped coming down. This seems safest, because on 14th August only the first fish to run were captured, and they may have been mainly those from between the trap and the lowest point netted. This basis of estimation gives for each sex a lower figure than would be obtained if estimates were based either on kelts trapped alone or on the sum of kelts trapped and fish netted. The ratio then in the case of males is the mean of 1 : 2.61 and 1 : 3.88—that is, 1 : 3.24. For females, the respective figures are 1 : 2.02 and 1 : 2.06, giving a mean of 1 : 2.04. Marked males numbered 2,509; the estimated number of unmarked males is 2,509 × 3.24. This gives a total number of males, marked and unmarked, of 10,638—in round figures, say, 10,500. Marked females numbered 9,921, whereas the unmarked fish were 2.04 times as numerous. Thus total females were 30,160—say, 30,000.

These 40,500 fish were not all the trout which spawned in the Selwyn. Fish of smaller average size are present and spawn in the Upper Selwyn and in a tributary, the Hororata, access to both of which waters was denied to any additional fish entering from the lake early in the winter of 1941, because the upper and lower waters were separated by a considerable length of dry bed. The estimate ignores also any small quantities of fish which spawned and returned to the lake before the trap was erected and any quantity, probably also small, which entered the spawning area after 14th August. The fact that a very big proportion of fish which entered the trap were already partially spent suggests the possibility of other fish having completed spawning lower down without ever running into the census area.

Lake Ellesmere is fed by several lesser tributaries, in some of which much spawning occurs. It is, however, questionable whether, even collectively, these other spawning grounds are as significant as those of the Selwyn. What additional number of fish escaped notice in the taking of this census need not concern us here, provided it is recognized that the 40,500 The production of eggs by each of a series of more than 50 fish, ranging in size from 13 to 26 of the Selwyn sub-system.

What number of eggs was produced by the proportion or fish accounted for in the Selwyn? The production of eggs by each of a series of more than 50 fish, ranging in size from 13 to 16 inches, was determined; only fish with firm ovaries were used for this purpose. From measurements of weekly samples of fish taken at the trap and supplemented by measurements of unmarked fish taken above it, the percentage of fish comprising the run falling into each size group was ascertained. The average production of eggs of fish in each inch group was then multiplied by the percentage of fish of that size group. The sum of the products was then divided by 100 to give the average production of all fish. This showed an average number of 2,050 eggs. The estimated production of eggs by the portion of the run accounted for is 2,050 × 30,000—61,500,000.

APPENDIX B

Interference with Natural Dispersal of Spawning Run at Selwyn River

The practice at the Selwyn River over many years was to install a fence below the trap-site early in May and to remove it when the trap was ready for use, usually at the end of May. Trapping continued usually into July. In many years, another fence was erected and maintained for a few weeks after the collecting of eggs ceased. Floods sometimes permitted fish to escape over the fence or trap. In other years the movement of fish into the eight miles of shingle-bedded stream above the trap was stopped for periods of two months or longer.

In 1930 and the succeeding six years, the average annual quantity of ova taken from the trap was 3,120,000—that is, about a twentieth of the estimated production of the run in 1941. Usually about 2,600 females were stripped to obtain the quantity of eggs hatched. The eggs taken represented approximately 60 per cent. of the full production of eggs by fish stripped. These fish had shed about a third of their eggs before entering the trap. Only 89 per cent. of such eggs as they contained when they entered were removed by stripping. After being stripped, fish were released below the trap.

In Appendix A it was shown that the average production of eggs by fish in the Selwyn was 2,050. Consideration of the numbers of fish stripped and of numbers of eggs obtained, as given for four years in the annual report of the North Canterbury Acclimatization Society in 1936, show an average stripping from females of 1,350 ova. Comparison of two series of trout taken from the trap in 1934, representing the same number of one-inch groups—16 to 22 inches—gave the following results. Trout with firm ovaries, not yet ready for stripping, contained 14,400 eggs. Ripe trout, in which eggs were loose, contained 9,600, or 67 per cent. of the quantity contained by hard fish. Thus a third of their eggs had been shed below the trap.

A random sample of twelve trout was taken in 1934 at the Selwyn, after they had been stripped by the experienced operative there. The fish were killed for examination. Quantities of eggs stripped from them and left in them after stripping were ascertained. The residual eggs amounted to 11.4 per cent. of the total. This is probably about the usual quantity left when partially spent trout are stripped for hatchery purposes in New Zealand. Smaller brown trout which had not deposited any eggs below the trap were stripped by the writer in Westland in 1934. Ten fish of 13 to 17 inches were killed for examination and were found to have retained 8.5 per cent. of their eggs. Seven females which died during or shortly following stripping had retained 5.8 per cent. of their eggs.

Certain fish were marked and returned above traps in Westland after they had been stripped so that it could be ascertained whether they would deposit residual eggs. They were not observed to make any attempt to spawn or to swim upstream beyond the nearest pool offering cover. There was difficulty in making the intended observations because fish usually attempted immediately to get downstream through the trap. Eggs removed by dissection from two fish, three days after they had been stripped, had lost their adhesive quality. Although such eggs were treated with milt of several males, they failed to develop when removed to a hatchery.

The quantity of eggs shed below the trap in the Selwyn in usual operational years is a third of the total yield of the fish stripped. As fish were released downstream after stripping, it could include the residual eggs, although available evidence suggests that no attempt is made to deposit these. The total quantity is thus 33 per cent. plus possibly 11.4 per cent. of 67 per cent.—say, in all, 40 per cent. With an average annual stripping of 3,120,000, the possible deposition below by the fish yielding these eggs would be about 2,020,000. Of this, the certain deposition is 1,560,000; the difference represents the residual eggs probably not deposited. This, however, is only a part—and possibly a very small part—of the total quantity of eggs deposited below the trap.

The total production by fish trapped was 5,140,000 eggs—that is, the sum of eggs shed

below the trap, eggs stripped and residual eggs—is about a twelfth of the production of 60,500,000 by the portion of the run accounted for in 1941. There is much to suggest that in many years the upstream movement of the greater part of the run is impeded by trapping operations, and it is possible that these fish, too, shed a portion of their eggs when they are held below.

An indication of the possible number of fish involved is afforded by a comparison of data relating to trapping in the two years 1939 and 1941. In 1939 a trap was installed on 17th May and was maintained until 4th July. Until 7th June, the practice of earlier years was followed of stripping ripe fish and releasing them downstream, together with any hard fish which entered. After 7th June and until 4th July, all fish which entered were just counted and released upstream. In 1941, fish were free to travel upstream until 7th June, when the trap was installed, and thereafter they were just counted and released up. The number of fish taken that year up to 4th July, at 8,333, was less than half the number captured in the same period in the earlier year. At the end of July, 1941, 326 females, from about eight miles above the trap, were examined. Of them, 80 per cent. were spent, 5 per cent. were partially spent, and 15 per cent. appeared ready or nearly ready to begin spawning. Freshes which might have stimulated spawning activity were absent in June and July.

The facts suggest that in earlier years, when barriers were kept in the river, often from early May until mid-July, the bulk of the spawning run was held back during the period in which most of the fish would have spawned. If the fish so held deposited the same proportion of their eggs below the trap as those fish trapped and stripped, a quantity of about 20,000,000 eggs would have been involved. This would be apart from any additional number shed by fish which spawned completely downstream without ever entering the trap.

The enforced concentration of fish below the trap would compel deposition of any eggs spawned in about half a mile of water, whereas otherwise this deposition might be spread over about eight and a half miles. Mr. John Digby, who for many years was in charge of the Selwyn trap, has in a personal communication described conditions there in the following words: "Before the big flood of 1923, it was possible to take a launch up to the trap-site; suitable shingle areas for spawning below it were negligible in extent. In recent years, shingle reaches have extended down for about half a mile below the trap—that is to say, reaches in part suitable for spawning. The lowest spawning I have seen occurs about half a mile down. It is fairly heavy there, but becomes progressively heavier as the trap is approached. In the hundred yards immediately below the trap, spawning is greatly heavier than anywhere lower down, and the same area is rooted over night after night as successive fish spawn. It was noticeable in stripping that the greatest number of eggs per fish were always obtained when weather conditions were suitable for fish to run straight on through to the trap from the lower reaches. In clear weather, with bright moonlight nights, few fish entered the trap, and such as did enter yielded far fewer eggs. It was noticeable, however, that at such times spawning activity did not cease; on the contrary, it was very intense immediately below the trap. In prolonged periods of bright weather, this intensive spawning below the trap caused shingle barriers to be formed across the stream immediately downstream from the trap. These barriers, over the top of which water still passed, raised the water level very appreciably at the trap. At such times it was necessary to dig through these barriers and try and smooth out the bed; but in continued bright weather such operations had to be repeated morning after morning as fresh ridges of shingle were formed by additional spawners. It was only in the 25 yards or so at the outside immediately below the trap that spawning was so intensive as to develop what were, in effect, big waves of shingle reaching from bank to bank. Not only during bright weather were such waves formed, but equally in any weather when for short intervals it was necessary to block the entrance of the trap."

These observations suggest strongly that many eggs must have been destroyed as redds already made were dug over again by relays of spawners or when they had to be levelled off by workmen.

APPENDIX C

Injuries to Trout in Stripping

In Westland in 1934, an endeavour was made to learn what losses of trout resulted from stripping. All fish stripped were marked by fin clipping and released below traps. Of 301 females and a number of males, seven fish, all females, were recovered dead from pools inspected regularly below traps. The fish were stripped by the writer, who was much less experienced than men employed regularly in obtaining eggs for hatcheries. More than usual pressure was used in obtaining eggs. A dozen fish killed for examination showed that the extrusion of ova had been 91.5 per cent. complete, as against 88.6 per cent. at the Selwyn, where the work of the usual operative was checked in the same year. The extrusion of ova from the fish in Westland which died was 94.5 complete. These data thus suggest an outside limit of 2.3 per cent. for losses of mature fish, which is probably not approached under usual conditions.

Where ova are obtained almost wholly from wild stocks, it is difficult to learn whether trout suffer injuries from which they slowly succumb. It is evident from reports (Kendall, 1920—subjoined discussion) that stripping of pond stocks can be carried out without substantial ensuing loss. Stokell (1936 and 1938) believed that heavy losses of trout which took place some miles above the trap-site in the Selwyn River were of fish which, although too incapacitated by stripping to return downstream to their usual feeding grounds in Lake Ellesmere, had got past the trap, below which they were released, or waited until it was removed and have then travelled several miles upstream. He had accepted the views of Armistead (1920) and Titcomb (Kendall, 1920—subjoined discussion) that stripped trout journey upstream and make redds if one or two eggs are left in them. He accepted the erroneous view of Kendall (1920) that ova do not naturally fall into the abdominal cavity and could not be extruded if displaced into it. He inferred that eggs found there in dead fish in the Selwyn had been displaced by handling at the trap.

The reaches of the Selwyn where heavy losses occurred are ones in which fish, which are not stripped, have access before the trap is installed and to which further fish have access after the trap is removed. Fish comprising the fraction of the run that is stripped were released below the trap, but could have gained access to these reaches after its removal.

Observations in New Zealand are entirely contrary to those of Armistead and Titcomb on the behaviour of stripped fish. Percival (1937) quotes Mr. J. Digby, who was in charge of the Selwyn trap for 14 years, as saying that of stripped females released below, only an occasional one returns to the trap, except when stripping is carried out on a rising river, when up to 10 per cent. might return within a few hours. The river did not rise in the period in question in 1932 and 1933. In Appendix B it was shown that in Westland in 1934, stripped fish released above a trap would not journey up beyond the nearest pool offering cover. There is thus nothing to suggest that any quantity of stripped fish would have sought to swim up the Selwyn to the areas where losses occurred. The reported differences of behaviour of trout after being stripped possibly arise from differences in the quantity of eggs left in fish in New Zealand and abroad.

The presence of eggs loose in the abdominal cavity of matured brown trout is usual, whether such fish have spawned naturally or have been stripped. Stokell reported eggs ranging in number from nine to 146 in 18 fish from the area above the Selwyn trap. Twelve trout killed by the writer at the Selwyn trap in 1934 after they had been stripped by the usual operator contained eggs, nearly all loose, ranging from 90 to 325—mean, 193. Only four contained fewer than the maximum found by Stokell in fish he assumed had been stripped. In Westland in 1934, ten smaller fish, killed after being stripped, contained from 28 to 190—mean, 93. In 1941, when no trout were stripped at the Selwyn, nine of ten kelts killed contained loose eggs ranging from two to 113—mean, 19. Of these fish, five also contained deflated residual eggs from earlier years. In 1934 in Westland, 14 small brown trout which had never been stripped,

in that or any other year, were captured as they returned down from spawning areas. Of them, 13 contained loose eggs, which ranged from one to 23. Percival (1937) has shown that displacement of ripe ova into the abdominal cavity is a usual and natural process in brown trout in New Zealand.

The failure of brown trout kelts to return downstream, with consequent loss of condition and sometimes death, as observed by Stokell in the Selwyn in 1932 and 1933, is usual in New Zealand when freshes do not take place. In 1932, freshes did not occur until October, when surviving fish immediately disappeared from upstream areas. The following year, in the absence of floods in winter, spring and summer, most fish finally died or were captured by anglers. In 1941, no trout were stripped in the Selwyn. For observational purposes, a trap was installed on 6th June and was maintained until carried away by a flood on 14th August. Approximately 28,000 trout passed upstream before 6th June. By 20th July, only 200 kelts had returned downstream. By the end of July, losses of fish were taking place at the upper limit of the accessible water, when 25 dead were counted in 440 yards of river. Farther down, where the concentration of fish was less, dead observed averaged about two per mile. By 13th August, 102 dead kelts had drifted down to the trap, but the number of live returning kelts had risen only to 544.

The following day, the first flood of the season occurred, and in a few hours, as the waters rose, 2,348 kelts were counted and great numbers of additional fish were seen before the trap was carried away. This disinclination of kelts to return to their usual feeding grounds without the stimulus of a flood is not peculiar to the Selwyn. It was observed by the writer in tributaries of the Bruce Stream in Westland in 1934 and in the Eglinton River in Southland in 1937. Percival (1937) reported like behaviour on the part of trout in the Opihi River in South Canterbury.

Such behaviour is not peculiar to brown trout. A substantial accumulation of rainbow kelts was noticed in a small tributary of Lake Rotomahana (Rotorua district) in September, 1947. The stream had not flooded for some months. Further, the quality of rainbow trout taken in November from the Tongariro River varies much from season to season according as or not floods have induced kelts to return to Lake Taupo.

APPENDIX D

Claims of Success of Hatchery Operations

Apart from indisputable evidence as to the useful part hatcheries played in the original liberations of trout in New Zealand and equally clear evidence that stocks in certain lakes have been maintained by periodical releases of fish sometimes produced in hatcheries, claims of the value of hatchery operations in New Zealand are more easy to find than evidence to support them. A perusal of successive annual reports of many administrative bodies discloses a marked tendency to prophesy improved angling at an ever-receding "near future," as a result of liberations made. This "horizon-chasing" often continues over periods of years until either the subject is just quietly dropped or the wheel of fortune rewards its persistent backers. Knowledge of the periodic fluctuation of populations, be they of fish, birds, mammals, or insects, indicates that he who prophesies persistently enough an increase of population will sooner or later be right—just as right, in fact, as he who prophesies the reverse.

Man is somewhat over-inclined to take credit for the occurrence of natural phenomena and also to observe only what his anticipations lead him to expect. In the Auckland Acclimatization District the opening of a hatchery of increased capacity in 1935 led to optimism among anglers as to improved fishing in the lower waters of the Waikato River. Rises of fish were observed where none had looked for rises before. A few under-sized fish captured were regarded as hatchery products, and success seemed only a season or so distant—and then the vision of the future faded as time elapsed without fruition of anticipations.

On a stream in that district the writer was accosted by a riparian owner, who pointed to the numerous yearlings present in the stream as evidence of the great advantages fingerlings had over smaller fry. He stated that in years of residence he had never seen results like these, until shortly before, when fish of the larger size were released. Careful inquiry showed conclusively that actually only fry of the usual size and number had been released there. The farmer had placed his own interpretation on a somewhat vaguely worded newspaper statement of proposed liberations. Later, he heard that fish had been released. He looked for and found what he expected to find. He would probably have been able to see plenty of fish of like size there in any earlier year had he looked. Incidentally, he might have observed that the stream has exceptionally fine spawning grounds which are used most successfully by many large fish.

In addition to occasions where evidence is lacking that any observable increase followed intensification of stocking, or where improved fishing may have resulted from either improved natural conditions—for instance, absence of big floods—and from a long period of weather suited to the efficient exercise of locally popular angling technique, two more serious cases require notice. The first is simply a case where an author of certain conclusions, reached incidentally to another study, states that data now available render untenable conclusions suggested earlier by more meagre data. Professor E. Percival, in his study of the effects of increased angling intensity, more especially on the stock of the trout in the Oreti River in Southland, accepted the then prevalent belief that stocking was on a significant scale (Percival, 1932). In a personal communication, he requests publication of the statement that he considers the changes in composition of stock observed in the Oreti and elsewhere, shortly following increased stocking, cannot, on further examination, be ascribed with any certainty to that cause.

The other case requires notice because in one district much publicity has persistently been given to views held locally as to the efficiency of maintenance liberations, and antagonism to new knowledge has resulted in a partial presentation of a case which has hitherto been ignored. The facts are that the South Canterbury Acclimatization Society did not operate a hatchery regulary until 1922–3, when temporary installations were made, to be followed in 1926–7 by a permanent structure of increased capacity. Sporadic releases of fish were made

from 1901–02 to 1922–3, amounting in one year to 100,000 fry, but for the balance of the period the mean annual release of fry does not appear to have exceeded 10,000 fry. From 1922–3 to 1926–7, the annual releases were about 160,000. Thereafter they increased to a mean of about 730,000 from 1926–7 to 1935–6. Licence revenue rose from about £390 per annum at the beginning of the century to about £510 in 1908, and thereafter fluctuated between £520 and £580 until 1923, when it stood at the lower figure. Thereafter it increased very strikingly to £890 in 1929 and £925 in 1932. (Revenue figures are approximate means for three-year periods centered on the years given.)

Locally, the increase in revenue is put forward as evidence of the benefits of hatchery work. Inquiry of anglers in South Canterbury discloses a fairly widely-held belief that fishing was very poor from about 1917–23, and many anglers, but not all, believe it has improved since hatchery operations were undertaken. Beyond question, a striking increase in sales of licences did succeed the inauguration of a stocking policy in South Canterbury. The inclination to attribute increased sales of licences to improved fishing resulting from more intensive stocking is as understandable as it is unwarranted when all the facts are taken into account.

Reference to reports of the three other large societies on the east coast of the South Island—North Canterbury, Otago, and Southland—disclosed a general long-term tendency for sale of licences to increase. The increase has never been at a steady rate, and the general upward trend is sometimes broken by short declines. The increase of 92 per cent. in licence revenue in South Canterbury between 1920 and 1930 is substantial. However, in the same period the revenue from fishing licences increased by 88 per cent. in North Canterbury, by 65 per cent. in Otago, and by 77 per cent. in Southland. These three societies had been stocking regularly since long before 1920.

Lack of dependence of revenue on rate of stocking is shown by earlier data from North Canterbury. In this district, revenue fell from a mean of £886 per annum for the years 1909, 1910, 1911 to £696 for the years 1919, 1920, 1921. Yet the rate of stocking with brown trout, which in both periods provided the bulk of the angling, increased from about 113,000 fish per annum in the five years preceding 1910 to 574,000 per annum in the five years preceding 1920. In both periods the bulk of the fish were released as fry; in both, much the same number of yearlings were released.

The Marlborough Acclimatization District is also on the east coast of the South Island. From 1931 to 1937, its revenue from fishing licences ranged between £30 and £46; but in 1940 it rose strikingly to £125. No hatchery was employed for trout eggs in the district. From about 1934 onwards, quantities of naturally-bred fingerlings (in a peak year, 120,000 of them) were transferred from portions of a drought-stricken tributary of the Wairau. The fish transferred represent only some of those naturally produced in one of many small streams. A very efficient ranger was engaged, and from then on the district was well patrolled. It is questioned whether any great increase of stock resulted from the salvaging of fish, or the more adequate patrolling of the territory. But much local publicity attended both the salvaging of fish and increased ranging activity.

Publicity given to fisheries activity, of kinds in which anglers have faith, will sell licences. To deny this would be to deny that advertising sells goods. Activity independently reported in newspapers is powerful propaganda. I am reminded of the comment of a South Island hatchery manager who produced great quantities of fry. It was that he did not know whether hatcheries increased stocks, but they certainly increased revenue.

In view of the foregoing facts, it is unsafe to ascribe increased sales of licences in South Canterbury to increased stocking. Actually, a considerable number of factors could have been responsible. These are:—

(1) Those factors which in most districts lead to increased sales—namely (a) growth of population, (b) reduction of the hours of labour, (c) improvement of economic conditions, and (d) improved access and means of transportation to fishing waters. (Note.—The influences of the first and the last of these four factors are discussed in some detail by Percival (1932) in relation to the Southland district.)

(2) Natural fluctuation in the density of stocks.

(3) Cessation in 1917 of the collection by the Marine Dapartment, for sale elsewhere, of the eggs of brown trout in the principal South Canterbury trout stream—the Opihi and its tributary, the Temuka. From 1907 onwards, quantities of approaching 1,000,000 eggs a year were removed, and it does not appear, from available reports, that the total return of fry in all years to streams of the South Canterbury district amounted to more than 100,000.

(4) The substitution by the South Canterbury Society from 1922 onwards of a policy of raiding local wild stocks to obtain eggs only for hatching and local distribution of products.

(5) The engagement in 1921–2 as ranger and hatchery curator of "Scotty" Main—a man of striking personality, who, in his day, was the best known and one of the most efficient of all acclimatization societies' employees.

(6) The provision of a second fine game fish in the rainbow trout. This was in Lake Alexandrina, a somewhat remote piece of water which only became easily accessible to large numbers of anglers during this period. The society's report of 1920 speaks of the lake as being fished by an increasing number of anglers each year and as promising to become one of the society's best assets. These fish were taken on the general licence.

(7) Quinnat salmon, which had spread to South Canterbury waters by natural dispersal earlier, increased by natural propagation strikingly during this period. Their taking, too, was permitted without special licence. Here are some extracts from reports of the local society in 1920: "There has again been no run of salmon in the Rangitata"—the principal salmon river; in 1922: "The run of salmon . . . the best on record . . . several very good catches recorded"; in 1923: "The run of salmon . . . has easily eclipsed any former year"; in 1924: "Decided to discontinue the issue of half-season licences. . . . Salmon fishing . . . available at the end of the season has justified this step being taken." Anglers who had previously taken out lower-priced short-term general licences, principally for salmon fishing, now had to pay the full fee.

It is clear that the increase in licence revenue in South Canterbury was largely paralleled in other districts irrespective of change in stocking policy. It is further clear that in South Canterbury a series of factors could have contributed to increased sales.

APPENDIX E

Change in Size of Trout in the Hutt River

The Hutt River is not to-day—and appears never to have been—a first-class trout stream. It is important only as the nearest river to Wellington which offers trout fishing. Somewhat fragmentary evidence of the angling history of the Hutt River shows unusual features. The evidence suggests that a more extensive change in size of fish may have taken place in the Hutt than in any other stream considered here, and that this change took place in a remarkably short space of time. Although the evidence as to size is often based on small samples, it seems wiser to put it on record than to dismiss certain peculiarities as attributable to the exigencies of sampling.

The earliest recorded releases of brown trout in the Hutt system were: October, 1876, 400; December, 1881, 600; March and November, 1882, 5,300; April, 1883, 2,500; 1884, 10,370; 1885, 24,050.

In the winters of 1884 and 1885, a few large fish were observed moving upstream to spawn.

The first angling season was in the summer of 1885–6. In that and the following season, successful anglers took on unspecified lures 130 trout of the high average weight of 6.76 lb. The number of fish in eight (presumed seasonal) records available varied from eight to 26 and the average weight shown by different records varied from 5.34 lb. to 9.22 lb. The heaviest individual was 13 lb. There is evidence that at this time, trout, in addition to being distributed over a considerable part of the readily accessible waters, were present in the short tidal reaches, and that sea-run fish were being netted illegally at the mouth.

In 1890, the fishing was reported as "fairly good."

In 1893, the river was stated to be "full of fish, but they are mostly small and not in as good condition as in other rivers, the largest fish forsaking its waters during the greater part of the year for the abundant food to be found in Wellington Harbour." Reference is also made to nets impeding the entrance of large trout from the sea.

This is the early history as given in contemporary reports of the local Acclimatization Society. The irregularity of the comments and the absence of data on catches after 1886–7 is regrettable. Additional evidence now available suggests that at no time subsequent to the season 1886–7 did average size of fish taken with minnow or with fly exceed 2 lb. until after 1930. These records, produced in Table IV, begin with the season 1887–8, and confirm the contemporaneous statement that fish were small by 1893, and suggest that this change from large fish to small fish was taking place several seasons earlier. The samples which indicate this are very small, but it is emphasized that each of eight samples which, in the first two seasons, showed an average size of 5.34 lb. or better, was small, the numbers of fish ranging from nine to 26.

Before the Hutt was opened to angling, the licence revenue from other waters—probably mainly the Wainui-o-mata—was about £40. In 1885–6, when the Hutt was first opened to angling, revenue from that portion of the district which includes it and the Wainui-o-mata was about £48. It rose to £50 the next season, and was in the next succeeding seasons £68, £80, £97, £111, £125. There is no evidence of a sharp rise following the catching of large fish in the Hutt. Although these fish were large, the number taken—16 per angler among the successful anglers—suggests a fairly sparse stock at that time.

It would appear that between 1876 and 1885 a number of trout, unmolested by nets or anglers, had been able to grow to a large size in the Hutt. Thereafter the selective effect of nets at the mouth and selective angling (probably with minnow) farther upstream removed a proportion of the large fish, and the presence of smaller fish became more apparent. The total fishing effort directed against the stock at that time could scarcely have had this effect unless the numbers of large trout then present were small. There is no reason to suppose that, within ten years from the first releases being made, the stock must have reached its

maximum density. It is possible also, as the contemporary report suggests, that, as numbers increased, fewer of the larger fish remained in fresh-water after spawning.

The claim that the river had become "full of fish—mostly small" by 1893 suggests that numbers increased after 1885–6. Records of 34 excursions made by four anglers in the Hutt in the eighteen-nineties show an average daily catch of 2.9 fish of an aggregate weight of 2.7 lb. This result is poor, even by present-day standards for other waters which have been considered. Records are available from one angler who fished the Hutt mainly with artificial fly, but sometimes with minnow, between 1887 and 1916. For 38 days between 1887 and 1890, he averaged 1.6 fish per day and the daily catch weighed 1.5 lb. For the periods 1890 to 1900, 1900 to 1910, and 1910 to 1916 respectively, the figures for excursions and numbers and weights per day are: 20 days, 1.6 fish, 1.7 lb.; 124 days, 0.5 fish, 1 lb.; and 55 days, 0.6 fish, weighing 0.8 lb. These data afford no evidence that the trout were ever in great abundance in the Hutt. They show a substantial reduction of the catch of the individual angler after the turn of the century.

FRONTISPIECE. The valley of the Main Water, looking downstream from about half-way along Zon II M; this shows the relatively wide alluvial flood-plain and the fairly steep hills forming the valle walls. In the distance can be seen the waters of the Pahautanui inlet, which connects with the ope sea through the gap in the hills on the extreme right.